WYOMING GAME & FISH DEPARTMENT

Fish Division

Standing Water Fishery

Guidelines for the Standardized Sampling
of
Lake and Reservoir Fisheries

Standing Water Fishery Assessment Committee

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First Edition

2002

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PREFACE

This manual harbors a wealth of information built from work on Wyoming waters. Practical guidelines devised by Wyoming fisheries managers are offered for standardized approaches to sampling standing waters. It is easy to understand and well worth the time invested in reading and then applying the guidelines.

In the way of fish sampling techniques, useful fishery statistics, advice about data processing and reporting, angler survey methods, and intensity of survey effort, there is no better manual to guide our actions.

I encourage wide use of the manual. Consult it often, follow the guidelines, and let no dust accumulate. Fish Division, standing water fisheries, the angling public, people interested in fish, and our friends, the fish, will benefit.

Robert W. Wiley
Fisheries Management Coordinator

INTRODUCTION

The goal of a fishery survey is to collect adequate and suitable information upon which responsible management decisions can be based or to measure the relative success of a management plan that has been implemented. The credibility of the information compiled depends on the way it is collected. Accuracy and precision of sampling data are paramount so changes over time can be measured.

Throughout the 20th century Wyoming Game & Fish Department fisheries workers followed no statewide standardized fish sampling protocol when conducting surveys on standing waters. Regional fisheries managers used different gear types and configurations, sampled at different times, applied different effort, and processed and reported data differently. Lack of standardization often precluded valid comparisons of data among regions, waters, and sampling periods. Reports rarely described data collection specifics. These concerns guided and sustained the effort to develop the standard methods presented in this manual.

Standardization of data collection, processing, and reporting has several objectives:

- Minimize ambiguity about when, how, and how often field data are collected.
- Ensure that fisheries managers collect data in consistent ways within and among regions.
- Enhance the opportunity for fisheries managers to compare standing water fishery data among years.
- Enhance the opportunity for fisheries managers to compare standing water fishery data throughout the state.
- Facilitate the comparison of data by standardizing the reporting format and content.
- Strengthen data sets for better defense of management decisions and policy implementation.

Justification is the single most important consideration before initiating any survey or sampling program. Rationale for sampling should be well thought out and objectives clearly defined and understood. Outlining goals, objectives, and expected outcomes of surveys compels biologists to critically think through sampling plans, encourages the contribution of input by fellow biologists, provides validation to administrators, and serves as a reference point for data analyses and summary. Limited manpower and resources mandate that data be useful, relevant, and defensible. Defensibility of data becomes increasingly important as anglers and other interested parties become better informed and more frequently scrutinize management decisions and policies.

This sampling manual was written to assist WGFD fisheries biologists plan, collect, and summarize data from standing water fisheries more efficiently and effectively. It specifically addresses surveys on waters exceeding 500 surface acres although much of what is presented may be applicable to smaller waters. The methods and strategies suggested herein should be considered a minimum. Circumstances or unique information needs may require more effort or other sampling procedures.

The manual is a guide to survey design, field work, analysis, and reporting. It is a dynamic document, revisable as techniques and methods change and improve. It is not so rigid that experience and circumstances do not permit adaptation for particular situations. Concerns about such issues as water level fluctuations, fish assemblages, weather conditions, or other uncontrollable factors may require modification of the procedures outlined in the manual. The foundation for standardization is consistency of data collection over time and decisions about sampling should be made on that basis.

Acknowledgements

Members of the Standing Water Fishery Assessment Committee did not work alone in writing this manual. Contributors included Paul Bailey, Joe Deromedi, Scott Gangl, Sheila Garl, Dirk Miller, Bob Wiley, and Dave Zafft. The manual was made considerably better following reviews by fish management personnel throughout Wyoming.

CHAPTER 1 -- CONSIDERATIONS

Public Relations

Increasing public interest in fish and wildlife affects all aspects of fisheries management. Questions about why biologists sample fish in lakes and streams, remove one sport fish in favor of another, use electricity to stun and collect fish, and so on have become common. To an angler any sport fish that dies as a result of fisheries work is a lost opportunity. Other people are sensitive about WGFD fisheries work because our actions displace, remove, or otherwise disturb fish.

High public interest in Wyoming's fisheries resources demands that we have clear goals and objectives for fish sampling and be able to clearly explain the amount and frequency of fish population sampling needed. We must clearly explain why we electrofish or use gillnets to gather information that helps manage for good fish populations that sustain good angling. Fish sampling is very visible and draws public interest and questions even though much of the work happens on weekdays. Gill netting and electrofishing easily attract attention and do remove some fish from the population. Removing fish from any water is a publicly sensitive issue.

As with all fisheries work, common sense should guide our actions when sampling fish populations. WGFD fish sampling activity frequently draws attention and stimulates curiosity from onlookers. A few guidelines may assist seasonal, new, and veteran employees alike in addressing public inquiries about fisheries work.

<u>Suggested Guidelines</u>

Have a well-defined management plan outlining prescribed fish sampling techniques. Be able to explain the need for sampling and the equipment used.

Identify all sampling equipment as WGFD equipment. For example, floats marking gillnet locations should be painted a bright color for visibility and clearly marked as WGFD property.

Make sure that boating equipment meets safety standards, is well maintained, and operated in accordance with boating regulations. WGFD provides official field clothing. Wear it when conducting field activities.

Assume the public always watches WGFD activity, especially fish sampling!

Literature Search

Peer reviewed and gray literature are the primary means for disseminating scientific information. Efficient use of relevant literature can strengthen study proposals, provide insight about observations and findings, support or refute preliminary conclusions, and help biologists and culturists stay abreast of advances in technology and methodology. Literature review conducted during the design of studies can help limit the amount of time and effort devoted to redundant research. All Wyoming fishery workers are encouraged to use the literature search options available to them. This section reviews several of the most readily available and useful alternatives.

Fish & Fisheries Worldwide

Fish & Fisheries Worldwide (FFW) is an online literature database available to all Fish Division personnel. The Fish Division contracts with NISC International to provide this service annually. The database provides thorough coverage of thousands of journal articles, books, monographs, pamphlets, conference proceedings, symposia, government reports, theses, dissertations, and scientific periodicals. More than 225,000 citations and some abstracts on all aspects of ichthyology, fisheries, and related aspects of aquaculture are available.

http://www.nisc.com

Internet Resources

The American Fisheries Society Computer User Section maintains a website with links to internet resources, government agencies, universities, and conservation and environmental organizations. In addition, the AFS offers recent issues of AFS journals online.

http://www.fisheries.org/cus/
http://www.fisheries.org/
http://afs.allenpress.com/afsonline/?request=index-html

UW and Community Colleges

The University of Wyoming and each of the seven Wyoming community colleges maintain libraries through which literature searches can be made on site. UW has an extensive collection of fisheries literature. Interlibrary loans can be arranged between any of these campuses. UW libraries can obtain fisheries literature from colleges and universities nationwide.

Local Public Libraries

All Wyoming county libraries are internet connected. Searches by author, title, and subject can be conducted through their website: “WYLDCat”. Interlibrary loans can be made between all libraries.

http://wyld.state.wy.us/

Locating Publications

Online databases and other resources are invaluable for identifying useful publications but accessing those publications requires additional effort. The list below offers several means of obtaining original articles or copies.

Obtain copies via interlibrary loan.
Request reprints directly from author.

Conduct literature search at UW or community college and photocopy there.
Regional Offices maintain subscriptions to some journals.
AFS journals online.

http://afs.allenpress.com/afsonline/?request=index-html

Sample Size

A common objective for sampling fish in standing waters is to detect changes in the size or structure of fish populations over time. Similarly, biologists may want to detect or monitor changes in fish size, weight, or condition. The ability to detect change is governed by sample variability and sample size (Bonar and Hubert 2002). Minimizing the variability in data generally lessens the size of the sample required to detect real change.

Before sampling, biologists should carefully consider the accuracy and precision of the data they are likely to collect. They should recognize and consider the important difference between the two. Accuracy is the ability of a measurement to match the actual value of the quantity being measured. Precision is the ability of a measurement to be consistently reproduced. Equally important, fishery managers must assess the level of risk they are willing to accept that the data collected will accurately reflect the population at large. Examination of data previously collected from a given water can be used to estimate the amount of sampling effort that may be required to obtain useful and reliable information. If previous data are not available, stepwise sampling following each day of netting can be used to calculate the number of samples needed to obtain a desired level of precision (Bonar et al. 2000). The desired level of precision will necessarily be tempered by the amount of time, personnel, and equipment available.

Gear sections in this manual suggest the number of nets which may reasonably be set in a given time and the Catch per Unit Effort section offers general guidelines when considering sample size. Published literature is available which offers specific guidelines (Bonar et al. 2000; Brown and Austen 1996; Miranda 1993; and Parkinson et al. 1988).

Fish Processing

The WGFD Fish Division uses English measurements. Data presented in text, tables, and figures are presented in English.

Length

Measure total length with the caudal fin compressed to the nearest 0.1 inch.

Weight

Measure weight to the nearest 0.1 pound.

Weights for very small fish are often inaccurate due to lack of scale precision, movement of fish, boat rocking, wind, and water accumulation on the scale. When the weight of small fish is desired and large numbers are available, batch weighing is recommended, whereby fish are weighed together and the weight is divided by the total number to reduce individual variation. To ensure accuracy special care must be taken if individuals are weighed separately.

All fish lengths and weights should be entered in the field onto the form:

Wyoming Standard Data Sheet - Standing Waters

An example form is available for duplication in Appendix I.

Length and weight data should be entered into Lakestn database.

Fish Disposal

Properly dispose of dead fish as discreetly as possible. With game fish in good condition, the preferred option is to clean, refrigerate, and return them to the Regional Office for distribution. Most Regional Offices maintain a list of charitable organizations that will accept good quality, fresh fish.   A Wildlife Donation Coupon should be completed for all donations of fish to a charitable organization.

CHAPTER 2 -- Sampling Techniques

Sinking Experimental Gill Net
(EG)

Sinking experimental gill nets are used to assess fishes in near shore and demersal habitats. They have been widely used throughout Wyoming since fishery biologists began sampling lakes and reservoirs. Multifilament nylon thread was used for many years until the 1970s, when lower visibility monofilament netting largely replaced multifilament. Many net configurations have been used throughout the state. Net lengths varied from 125 – 200 ft and mesh sizes varied from ½ – 3 in. Most nets had meshes sewn in graduated order but in the late 1980s several crews began using random ordered mesh nets because of concern that graduated order misrepresented the size distribution of fish in standing waters.

Discussions with many biologists led to the decision to adopt a statewide standard EG that is comprised of eight panels of different mesh sizes placed in an established order as described in **Specifications**. The order is a compromise between graduated and random and will yield good size distribution data while allowing for statistical comparison of data between sites and sampling events.

EGs can be set at any depth but are most often anchored near shore in water four to six ft deep and extended perpendicularly outward. The smallest mesh should consistently be set nearest the shore to improve statistical comparisons between sets. Since EGs are submerged in water with little or no current and are constructed with a lead bottom line they do not drift and only small weights are necessary to keep them in place. Sinking nets are generally submerged sufficiently so they do not present a hazard to boaters. Floats should be clearly labeled as belonging to WGFD. GPS coordinates should be saved or recorded for ease of location upon net retrieval and for site replication. This is particularly helpful when different biologists set and retrieve nets.

<u>Specifications</u>

Sinking Experimental Monofilament Gill Nets (EG):

Polycore top line.
Leadcore bottom line.

160 ft x 6 ft with eight, 20 ft panels of the following mesh sizes in specified order:

#69 monofilament thread - ¾”, 1” square mesh.
#104 monofilament thread - 1¼” 1½” 1¾” square mesh.
#139 monofilament thread – 2” 2¼” 2½” square mesh.

Mesh Order:

¾”, 1 ½”, 2 ¼”, 1 ¼”, 1 ¾”, 2 ½”, 1”, 2”

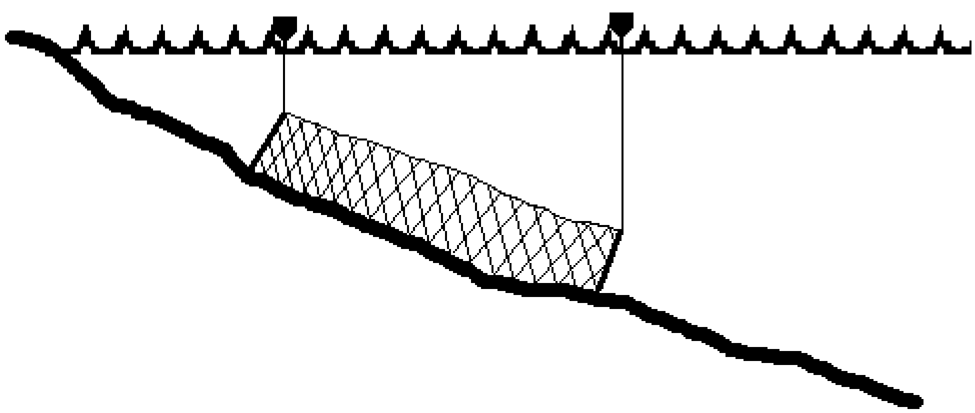
Application

EGs are useful for obtaining length and weight data and to collect fish for disease analysis, genetic samples, bony structures for aging, etc. Analysis of EG data yields estimates of relative abundance, size structure, year class strength, and species composition for many species. Catch data are computed using Catch Per Unit Effort (CPUE) and are expressed in number of fish per net hour. When surface-oriented fish species are the primary focus of netting, floating nets are a more effective and time efficient sampling tool.

EGs should be set during late afternoon and should be pulled as soon as practical the following morning. However, EGs may be effective during daylight hours for some species and can be set for short duration when minimizing mortality is a consideration. Two hour daytime EG sets in Glendo Reservoir caught up to 10 WAE per hour when population levels were very high.

EGs can be particularly effective in capturing nongame fish species, a consideration which can affect the number of nets that can be retrieved in a normal work day. Some fish species, particularly spiny rayed fishes and those with serrated fins, can be difficult to remove and can tear fine meshes easily. Large CRP are particularly damaging to gill nets. It is advisable to limit the number of EGs set overnight where large numbers of BLB, CCF, CRP, QBK, RCS, UTC, YEP or suckers occur due of the time and effort required to remove them and because of potential damage to the nets.

EG data forms should include net set and retrieval date and time, hours set, location, water depth, weather conditions, and names of workers (use Wyoming Data Sheet for Standing Waters). Data should be kept separate for each net and, at a minimum, the number of fish of every species captured must be recorded for each net. Biological data should be recorded for species of interest. All raw data should be entered into the Lakestn database.



Stylized illustration of a correctly set sinking experimental gill net.

Effort

EGs are generally the best method to assess fish nearshore. EGs should be used in all lakes unless most fish are known to be pelagic or where nongame fish are exceedingly abundant. For lakes supporting mixed salmonid and other sport fish communities, both FGs and EGs should be set. Virtually all active fish species are vulnerable to EGs although those closely associated with structure like SMB and LMB are infrequently captured. EGs do not efficiently catch BBT because of their slender, sinuous body form. EGs generally yield a poor assessment of young-of-the-year fishes.

Trout

EGs should be set in late spring or early summer to evaluate overwinter survival, particularly of first year fish, and to assess growth and body condition following the winter period. Biologists must consider timing of spawning and sample before or after the spawning season. Otherwise, distribution and behavior of spawning trout might compromise year-to-year comparability of data. EG sampling should be scheduled before stocking in spring-stocked waters to avoid capture of newly released fish. In trout waters, EGs are particularly useful for obtaining length and weight information and for monitoring trout cohort strength and relative population density over time.

In most waters, three overnight EGs can easily be processed in one day. A minimum of three EG sets on a single night should be planned for all waters greater than 500 surface acres. Larger waters require more effort. Three days of net retrieval should be devoted to sampling waters larger than 2,500 surface acres, for a total of 9 overnight sets. For very large waters biologists should use historic netting information and experience to weigh available manpower against information needs and tailor a netting program to the specific water.

Nets should be as widely distributed throughout each water as practical. If standardized sites have been established previously and represent a long term dataset, they should continue to be used. If not, sites should be identified that offer a representative sample of available habitat types. Net locations and sampling dates should be standardized for optimal trend data. Reservoirs which experience severe annual water level fluctuations present challenges that must be dealt with on a water by water basis.

Where practical, sampling should be conducted annually for at least three years to establish baseline data. Following the establishment of a consecutive year data set, sampling frequency may be reduced to levels adequate to monitor changes in the fish population. At a minimum, sampling frequency should be set so that entire cohorts are not missed. For example, if average longevity for trout in a particular water is four years, sampling should be scheduled at least every three years. Evidence which suggests a significant change in the fish populations of interest may prompt interim or more intensive sampling.

Walleye

EGs are the best sampling device for WAE since they are generally near the bottom. When used to capture WAE, EGs should be set in late summer and fall. EGs yield WAE relative abundance data following the majority of annual fishing mortality and provide information about body condition as fish enter winter. They also offer insight about yearling survival and can be used to predict future fishing opportunity.

Special Considerations

EGs should be pulled tight when setting to avoid net bunching.

Extra care should be taken when setting in areas known to have submerged debris or large rocks to minimize snagging.

Floating Experimental Gill Net
(FG)

Floating experimental gill nets are used to capture pelagic fish and are particularly useful for monitoring RBT, CUT, and KOE. During the late summer and fall months they may also be useful for monitoring WAE and catfish, where small pelagic forage fish attract these normally shore and bottom oriented piscivores to the open water. A particular and important advantage of FGs is that they entangle few nongame fish. By minimizing the catch of nongame fish, nets are retrieved much faster and damage to the net is negligible. Through 2002 FGs have not been a widely used fish sampling tool in Wyoming.

FG mesh sizes are the same as sinking gill nets (EG) but are placed in graduated order. The nets should be set over water at least 15 ft deep to minimize the capture of fish generally associated with the bottom. Orientation to the shoreline is irrelevant. Floating nets must be anchored more heavily than sinking nets to prevent drift in substantial winds. They should be set parallel to the prevailing wind direction to minimize curving of the net. Float lines should be about 1 ½ times the water depth and anchors should be set at a considerable angle from the net so the resulting tension minimizes sagging. Nets should be well marked with several large, brightly colored floats placed along the top line so boaters can avoid contact. Highly visible floats also help biologists easily locate nets since even slight waves make it difficult to locate low profile markers from a distance. Floats should be clearly labeled as belonging to the WGFD. GPS coordinates should be saved or recorded for ease of location upon net retrieval and for site replication. This is particularly helpful when different biologists set and retrieve nets.

<u>Specifications</u>

Floating Experimental Monofilament Gill Nets (FG):

Polycore top line complete with Spongex or equivalent floats.
Leadcore bottom line.

160 ft x 8 ft with eight, 20 ft panels of the following mesh sizes in graduated order:

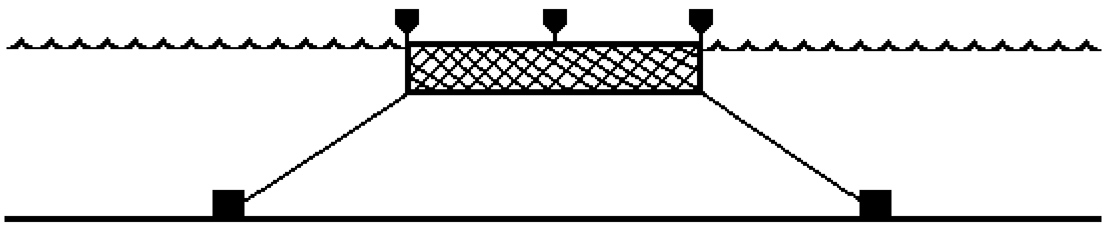
#69 monofilament thread - ¾”, 1” square mesh.
#104 monofilament thread - 1¼” 1½” 1¾” square mesh.
#139 monofilament thread – 2” 2¼” 2½” square mesh.

<u>Application</u>

FGs are useful for obtaining length and weight data and to collect disease samples, genetic samples, bony structures for aging, etc. Analysis of FG data yields estimates of relative abundance, size structure, year class strength, and species composition for many sport fish species. Catch data are computed using Catch Per Unit Effort (CPUE) and are expressed in number of fish per net hour. When fish species are bottom-oriented or nongame fish species are the primary focus of netting, FGs are not appropriate.

FGs should be set during late afternoon or evening and should be pulled as soon as practical the following morning. FGs are generally ineffective during daylight hours as fish seldom cruise directly below the surface during the day. Also, recreational boat activity is heaviest during daylight hours and floating nets present a hazard to boaters. Whenever possible floating nets should be located away from areas where boat traffic is expected.

FG data forms should include set and retrieved date and time, hours set, location, water depth, weather conditions, and names of workers (use Wyoming Data Sheet - Standing Waters). Data should be kept separate for each net and, at a minimum, the number of fish of every species captured must be recorded for each net. Biological data should be recorded for species of interest. All raw data should be entered into the Lakestn database.



Stylized illustration of a correctly set floating gill net.

Effort

FGs should be used in all lakes which support fish species of interest inhabiting offshore waters. For lakes in which pelagic salmonids are the principal fish of interest, FGs can be the primary or only type of net used. FGs greatly reduce the catch of nongame fish species and thereby the amount of time required to retrieve nets. Consequently, more FGs can be retrieved in the same amount of time as would be required to retrieve EGs. In most cases EGs will also be needed to assess fish nearshore. For lakes which support mixed salmonid and other sport fish communities both FGs and EGs should be set.

Trout

FGs should be set in spring or early summer to evaluate overwinter survival, particularly of first year fish, and to assess growth and body condition following the winter period. Biologists must consider timing of spawning and sample before or after the spawning season. Otherwise, distribution and behavior of spawning trout might compromise year-to-year comparability of data. FG sampling should be scheduled prior to stocking in spring-stocked waters to avoid capture of newly released fish. In trout waters FGs are particularly useful for obtaining length and weight information and for monitoring trout cohort strength and relative population density over time.

In most waters four overnight FGs can easily be processed in one day. A minimum of four FG sets on a single night should be planned for all waters greater than 500 surface acres. Larger waters require more effort. Three days of net retrieval should be devoted to sampling waters larger than 2,500 surface acres, for a total of 12 overnight sets. For very large waters biologists should use historic netting information and experience to weigh available manpower against information needs and tailor a netting program to the specific water.

Nets should be as widely distributed throughout each water as practical. Net locations and sampling dates should be standardized for optimal trend data. Reservoirs which experience severe annual water level fluctuations present challenges which must be dealt with on a water by water basis.

Where practical, sampling should be conducted annually for at least three years to establish baseline data. Following the establishment of a consecutive year data set, sampling frequency may be reduced to levels adequate to monitor changes in the fish population. At a minimum, sampling frequency should be set so that entire cohorts are not missed. For example, if average longevity for trout in a particular water is four years, sampling should be scheduled at least every three years. Evidence which suggests a significant change in the fish populations of interest may prompt interim or more intensive sampling.

Walleye

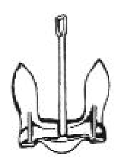
Because EGs often catch many non-target fish species, time and effort can be reduced by using FGs to catch WAE in waters where pelagic prey fish species are abundant and where EGs have traditionally been the primary fish collection gear. When used to capture WAE, FGs should be set in late summer and fall months when WAE are drawn to the surface by pelagic prey. FGs yield WAE relative abundance data following the majority of annual fishing mortality and provide information about body condition as fish enter winter. They also offer insight about yearling survival and can be used to predict future fishing opportunity.

Special Considerations

Tension on the net can best be achieved by attaching the final float to the end of the net, then backing the boat away from the net as the anchored line is fed out, finally releasing the anchor to arc down to the bottom of its own accord.

During times and in areas of suspected night recreational boat use, FGs should be equipped with lighted and light-reflective floats or should not be used.

Securely anchoring FGs over sand substrate can be difficult during high winds. Additional weight or special anchors may be necessary if high winds are expected. Navy-style anchors as shown below are particularly effective in sand and mud substrates.



Trap Net
(TN)

Trap nets are primarily used to sample fish that move into littoral areas and travel parallel to shore. This passive gear is useful for sampling panfish, northern pike, trout, and some nongame fish species. TNs may also be useful for removing undesirable fish for population reduction. Fish mortality in TNs is rare so these nets are well suited for capturing fish for transplanting or spawning. Also, once set TNs can be quickly and easily checked and reset without removing the entire net from the water.

This manual recommends the use of EGs and FGs as principal fish sampling tools in standing waters and TNs are not generally employed in standardized sampling programs. The use of TNs should be considered supplemental to gill nets and can be used when biologists believe near shore dwelling fish species are inadequately sampled.

TNs should be set as perpendicular to shore as possible with the top of the first rectangular frame hoop near the water surface (< 1 ft under water) and located to maximize use of the lead. The TN is stretched between a metal stake at the water's edge and a weight of about 20 pounds attached to the heavy cord that closes the cod end of the trap. A highly visible float, clearly marked as WGFD property, should be attached to the weight with a section of rope long enough to reach the water surface. Highly visible floats help locate nets when waves limit sight distance. Net locations should be marked with GPS units and coordinates saved to help retrieve nets and replicate site locations.

<u>Specifications</u>

Trap Nets (TN):

Two rectangular frames, 3 ft by 4 ft of one inch conduit, followed by five hoops of galvanized steel.

Throats on the first and third hoops.

Single center tied lead 50 ft long by 4 ft deep of ¼ inch mesh; top and bottom ropes of ¼ inch braided nylon with lead weights and Spongex floats.

¼ inch square mesh, knotless nylon netting (44 lb Delta Extra Heavy) throughout.

Nets treated with diluted green Plasti-net or equivalent net preservative.

<u>Application</u>

TNs are useful for obtaining length and weight data and for collecting fish for disease, genetics or aging structure samples. Estimates of relative abundance, size structure, year class strength, and species composition for many fish species can be obtained through analysis of TN data. Catch Per Unit of Effort (CPUE) is used to compute catch data that are expressed in number of fish per net night.

In addition to the above, TNs are used for population sampling, collecting fish for transplanting, salvaging sport fish species, and removal of undesirable fish. TNs have been used effectively to capture various sizes of NOP in Keyhole Reservoir and TIM in LAK Reservoir.

TNs should be set in the late afternoon or early evening and should be pulled as soon as practical the following morning. TN tend to be more effective during late evening and nighttime hours as fish tend to cruise shoreline areas more during these times. If angler boating activity is concentrated along shorelines during daylight hours, TNs may be a hindrance to boating anglers. If possible, TNs should be located away from areas where swimmers or boat traffic are expected.

TN data forms should include set and retrieved date and time, number of nights set, location, weather conditions, and names of workers (use Wyoming Data Sheet - Standing Waters). Data should be kept separate for each net and, at a minimum; the number of fish of every species captured must be recorded for each net. Biological data should be recorded for species of interest. All raw data should be entered into the Lakestn database.

Effort

TNs are most useful in lakes supporting shoreline-oriented fish species of interest. In most cases EGs will also be needed to assess fish nearshore. However, TNs may be a particularly valuable trout sampling tool during spawning periods when trout are drawn near shore because TNs are a nonlethal capture gear. For lakes which support mixed salmonid and other sport fish communities, TN may offer additional insight beyond that gained through the use of EG.

Four overnight TNs can usually be processed in one day even when other types of nets are used because fish will remain alive and unhurt in TNs for long periods. When used, a minimum of four TN sets on a single night should be planned for all waters greater than 500 surface acres. Three days of net retrieval should be devoted to sampling waters larger than 2,500 surface acres, for a total of 12 overnight sets. For very large waters biologists should use historic netting information and experience to weigh available manpower against information needs and tailor a netting program to the specific water.

Nets should be as widely distributed throughout each water as practical and set in a variety of habitat types. Net locations and sampling dates should be standardized for optimal trend data. Reservoirs which experience severe annual water level fluctuations present challenges which must be dealt with on a water by water basis.

Where practical, sampling should be conducted annually for at least three years to establish baseline data. Following the establishment of a consecutive year data set, sampling frequency may be reduced to levels adequate to monitor changes in the fish population. At a minimum, sampling frequency should be set so that entire cohorts are not missed. For example, if average longevity for the target species in a particular water is four years, sampling should be scheduled at least every three years. Evidence which suggests a significant change in the fish populations of interest may prompt interim or more intensive sampling.

Special Considerations

High winds that blow from a direction that is perpendicular to the shoreline where TNs are set can roll the nets, rendering them ineffective. If possible set TNs in more sheltered areas or along shorelines parallel to wind direction.

TNs should be maintained in good condition with no holes. Holes, particularly in the cod section of the net, are readily located by fish as they have much time to discover escape opportunities.

Muskrats can be particularly damaging to TNs. When present in substantial numbers, other gears might be more appropriate.

Minnow Seine
(MS)

Minnow seines have been used sporadically by fisheries biologists to assess presence or absence and relative abundance of forage fish species and young sport fish species throughout Wyoming. At least two waters, Keyhole and Boysen Reservoirs, have been seined in similar manner annually for many years. Shoreline seining in late summer with a small mesh seine can effectively sample young-of-the-year sport fish, nongame, and forage species but inferences about population status are difficult since the variance in catch is often high. A MS can also be used to salvage fish, collect forage species for transplanting, or remove undesirable species from waters.

<u>Specifications</u>

Minnow Seine:

50 ft by 6 ft with 1/8-inch (ace or delta) mesh with a 4 ft bag.
Float line with 3 in by 1 ½ in Spongex or equivalent floats spaced on 18 in centers.
Lead line with #10 barrel lead sinkers spaced on 12 in centers.

Brails: 6 ft long by 1 ½ in diameter wood poles.

<u>Application</u>

Many factors influence the catch of young fish by MS. Shallow waters are subject to frequent, wide fluctuations in water temperature. Time of day, season, wind, barometric pressure and a host of other environmental parameters alter the movement pattern of small fishes as do the presence and abundance of predators. Although generally not quantified and uncontrollable, these influences dramatically affect the catch of small fish and should be considered when using MS data to assess recruitment and year class strength.

In addition to obtaining length, weight, relative abundance, year class strength, and growth data for young-of-the-year sport fish, a MS is useful for investigating presence, relative abundance, and species composition information for forage species. A MS can also be used to collect disease and genetic samples as well as bony structures for age and growth or oxytetracycline (OTC) marking analysis. Catch data are computed using Catch Per Unit Effort (CPUE) and are presented as number of fish per haul and percent occurrence.

Areas to be seined should be less than five ft in depth and must be relatively free of large rocks, brush, or other snags that cause the seine to hang up and lift off the bottom. Care should be taken to avoid seining into the wind as the wind can catch the seine and pull it off the bottom, allowing fish to escape. As practical, standardized sites should be established and coordinates recorded using GPS.

MS data forms should include date, location, weather conditions, habitat type sampled (i.e. sand, mud or rubble bottom), and names of workers (use Wyoming Data Sheet - Standing Waters). The number of fish of every species captured must be recorded for each haul.

<u>Effort</u>

A MS should be used to address specific questions or to continue standardized sampling programs where useful. Generally, 12-15 MS hauls can be done in one day if no other sampling is being done that day. Shoreline substrate types should be sampled in proportion to their occurrence around the lake.

A MS is used primarily during daylight hours, but evening or night sampling can be effective if the target species tends to move to shallow waters during these periods. Small CCF have only been effectively seined from Hawk Springs Reservoir after dark. Care should be taken to avoid MS sampling immediately after the passage of a cold front that tends to cool shallow waters.

Special Considerations

MS data are frequently highly variable. Using MS data to assess and predict recruitment and year class strength must be done with caution. MS data may be most useful simply for confirming the presence of fish species inhabiting near shore habitats.

Care should be taken while seining since drop offs, rocks and other obstacles are potential hazards to workers, particularly in low visibility waters.

Purse Seine
(LP & SP)

Purse seines are used in Wyoming to assess fishes utilizing offshore habitats. RBT, CUT, and KOE comprise most of the sport fish catch. Prey species like GZS and EMS can be targeted when information about forage fish availability or relative abundance is desired. Knowledge about spatial behavior helps determine the best times to sample with the purse seine. Schooling behavior significantly influences catch so the purse seine is not a valid tool for population estimation although relative densities can be evaluated. Catch can vary greatly between hauls depending on the degree of fish clustering. An advantage to sampling with the purse seine is that fish are not harmed and can be released after processing. Very few nongame fish are captured by the purse seine.

Since Wyoming uses two purse seines of different depth we have the ability to sample deep and relatively shallow waters. Both nets are constructed with 3/8 inch mesh so that small fish are sampled equally well with either net. Great care must be taken to avoid contact with the bottom unless the substrate is known to be free from obstructions like rocks and submerged trees. Even silt and mud bottoms can interfere with retrieval in waters too shallow because the net may roll up along the bottom line as it is pursed.

The 60 ft deep purse seine surrounds about 1.1 acres and fishes effectively to a depth of approximately 45 ft because the bottom of the net lifts as it is pursed. The 30 ft deep net effectively fishes to about 25 ft of depth and encircles 2/3 of an acre. The speed at which the purse line is pulled affects the amount by which the bottom of the net is lifted but a relatively fast retrieval is necessary to minimize fish escapement. Experience teaches the most efficient speed at which the net can be closed.

Purse seining is very sensitive to wind, a constant threat on Wyoming's large standing waters. Not only do the machinery, moving equipment, and rocking boats make the operation dangerous but net setting is made difficult, thus affecting fish catch. Purse seining should not be done when winds exceed 10-15 mph.

Standardized locations have been used for many years on waters which historically have been sampled annually (Alcova and Buffalo Bill Reservoirs). Within the past several years sampling sites have been identified with GPS whereas they had previously been located by shore reference. Annual water fluctuations compel us to ascertain depth at each site using an echosounder prior to setting the net. Generally no attempt is made to locate fish concentrations before setting because the purse seine is used to assess relative abundance.

The Reservoir Management Unit in Casper maintains and operates the purse seines.

<u>Specifications:</u>

Large Purse Seine (LP):

775 ft long.
60 ft deep.
3/8 in mesh throughout, except bottom 3 ft of 1 in mesh to assist with pursing.
30 ft of breast line at each end.

Small Purse Seine (SP):

600 ft long.
30 ft deep.
3/8 in mesh throughout, no large mesh bottom mesh.
No breast line.

Application

Purse seines are useful for capturing fish live and for assessing pelagic fishes. Length, weight, relative density, size structure, and species composition data are obtained for open water fish species. The SP has been particularly valuable in partitioning targets when sonar surveys are conducted. Catch data are computed using Catch Per Unit Effort (CPUE) and are expressed in number of fish per haul.

The purse seine is used only during daylight hours. Attempts in the 1980s to conduct purse seine work at night in Flaming Gorge Reservoir illustrated the dangers inherent in the operation after dark.

Purse seine data forms should include type of net, set and retrieved date and time, location, water depth, weather conditions, and names of workers (use Wyoming Data Sheet - Standing Waters). The number of fish of every species captured must be recorded for each net. Biological data should be recorded for all fish. All raw data should be entered into the Lakestn database.

Effort

Because they are labor intensive and expensive to operate, purse seines should be used to address specific questions or to continue standardized sampling programs where useful. Generally 7-8 sets with the LP constitutes a full day. Up to 15 hauls with the SP can be taken per day in good weather. Except for the largest standing waters, one haul should be taken for every 200-250 surface acres unless little can be gained by continued seining. For example, catch in 2001 in every haul on Keyhole Reservoir consisted of many crappie, some CRP, and virtually nothing else. Although Keyhole exceeds 9,000 surface acres at full pool, little additional insight was gained after 10 purse seine hauls. The SP was particularly valuable on Keyhole, however, in documenting the dramatic decline in the very dense CRP in the early 1990s and has been useful in monitoring the continued suppression of CRP numbers since then through FMSN's management efforts. When used to verify sonar targets, purse seine sites and effort should be coordinated with sonar work.

The purse seine should be used when the primary species of interest are best distributed throughout the open water and most vulnerable to the net. Spawning behavior of trout often draws those fish near shore or into tributary streams. Very early spring and late fall months generally present inclement weather and unfavorable purse seine conditions.

Special Considerations

Attention to the boats while pursing and net retrieval is critical to successful purse seining. Without constant vigilance by the operator, the net can foul props and be damaged.

Machinery and rocking boats make purse seining dangerous. Safety is paramount. The supervisor should be constantly aware of potential dangers.

Hydroacoustics (Sonar)
(HY)

The WGFD began sampling fish populations with sonar in 1996. Recent research conducted by the Reservoir Management Unit demonstrated that sonar surveys produce repeatable results, thus demonstrating its utility for standardized sampling (Gangl and Whaley, In preparation). Sonar can be used to gather information on fish population density and size distribution, and these data provide information on the dynamics of fish populations. Sampling with sonar has several advantages over traditional gears, including:

- Quantitative.
  - Sonar estimates fish numbers and sampled volume to calculate fish density.
  - It is also unbiased because all sizes of fish can be tracked with sonar.
- Statistically robust.
  - Sonar surveys can collect a large sample, providing a high level of precision.
  - Sonar is an active sampling gear, thus reducing the effects of fish distributions or behavior on sample estimates of variance.
  - Results of sonar surveys can be tested for statistical significance with high levels of confidence.
- Estimates multiple parameters.
  - In addition to density and size estimates, sonar can be used to collect information on fish horizontal and vertical distributions.
  - Sonar can also sample much of the water column not sampled by other gears.
- Unobtrusive.
  - Fishes and their environments are not harmed by sonar sampling.
- Low operating and labor costs.

Sonar does have several limitations, including:

- Lack of species identification.
  - Netting is still required to determine species composition and to collect detailed biological data.
- Difficulty sampling near boundaries.
  - Fish cannot be detected very near the surface or the substrate.
  - Acoustic sampling is generally not possible in water less than 25-ft deep.
  - When fish are strongly associated with these habitats, sonar estimates can be significantly biased.

<u>Specifications:</u>

Sonar Field Equipment:

HTI Model 241 scientific grade echosounder, 200 kHz operating frequency.
6^{o} split-beam transducer, aimed horizontally.
15^{o} split-beam transducer, aimed vertically.
Oscilloscope.
Laptop computer loaded with HTI-DEP software.
Digital Audio Tape recorder.

Post-Processing Equipment:

HTI Echoscape software.

Microsoft Access queries, available at https://www.dnr.state.mn.us

Application

Sonar can be used to sample pelagic fish populations in water 25 ft deep or deeper. Any fish species that occupies the pelagic regions of a lake or reservoir can be sampled. Sport fish commonly sampled by sonar include RBT, KOE, and CUT. Forage fish, including GZS and EMS, can also be sampled. Sonar should not be used to sample littoral or benthic species such as WAE, CCF, or LAT unless prior knowledge exists which suggests those species will suspend in the water column during sampling.

Sonar results can be used for many management applications. Sonar information includes, but is not limited to:

- Population assessment.
- Size structure.
- Forage abundance or biomass.
- Recruitment monitoring.
- Impacts of predation.
- Brood stock monitoring.
- Mortality estimates.
- Effects of water levels and flows.
- Stocking success.
- Spatial distributions.
- Temporal distributions.

This list covers a broad range of applications for sonar data. Prior to any survey taking place, clearly defined survey objectives should be outlined to ensure that the survey is designed to meet data requirements and to facilitate data processing and analysis.

Effort

Sonar sampling effort (number of transects) will depend on the level of precision desired for the resulting estimates. Things to consider when planning a sonar survey include:

- Vertical fish distribution at time of sample.
- Behavior of fish species of interest.
- Time of sample, daily.
- Time of sample, seasonally.
- Patchiness of fish distributions at time of sample.

When fish are patchily distributed and/or have an overall low mean density, the sample coefficient of variation will be much higher than when fish are homogenously distributed and/or have a high population density. Diurnal and nocturnal fish behaviors can affect density estimates. For example, KOE tend to school during daylight, making enumeration of individual fish impossible. Therefore, sonar surveys for KOE should be conducted at night when fish disperse to feed. Alternatively, RBT tend to be dispersed and can be sampled during daylight hours.

Seasonal fish distributions can also affect density estimates. Trout may occupy shallow waters near shore during spring or fall due to spawning behaviors, affecting their vulnerability to pelagic sonar sampling. Sampling should be done when most of the fish are offshore, usually during the summer months.

The position of fish in the water column will determine whether they can be sampled or not. For example, fish very near the surface or very near the bottom cannot be sampled effectively with sonar. Thus, preliminary knowledge of the behavior displayed by species of interest is paramount to the design of successful sonar surveys.

Special Considerations

Sonar surveys should only be conducted under calm (wind <10 mph) conditions. Research conducted by the Reservoir Management Unit (Gangl and Whaley In preparation) shows that surveys conducted during windy conditions do not produce repeatable results.

Fish population estimation using hydroacoustics requires sophisticated scientific grade sonar equipment and specialized training in equipment operation and data analyses. Wyoming's HTI sonar system is operated by the Reservoir Management Unit. All hydroacoustic surveys are conducted by the Reservoir Management Unit in collaboration with regional fishery biologists.

For more detailed discussions on survey design and planning, refer to the Selected Literature.

Selected Literature

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Boat Electrofishing
(EF)

Boat electrofishing is an active sampling tool used primarily to capture littoral dwelling species or species that enter the littoral zone. Although EF can be used to sample all fish species, it is particularly useful for sampling panfish, LMB and SMB, and young-of-the-year and yearling WAE. Netters can attempt to collect all fish that are stunned in the electrical field or they can be selective and target species or sizes of interest. Although historically not used often for sampling Wyoming's standing water fisheries, this tool offers great possibilities and will be increasingly used as its potential is fully realized.

EF on standing waters is most effective near shore where water is less than six ft deep and when winds are calm. For most applications, sampling started just after sunset will increase sampling efficiency as fish become more active and move into the shallows. Stations, typically with varied habitat types (weed beds, brush piles, fallen trees, rocky shoreline, etc.), should be established and sampled for a predetermined time.

Specifications

Standing water electrofishing boat (EF):

Capable of producing 300-400 volts and up to 10 amps of pulsed DC current at 120 cycles per second.

Live well of sufficient size and capability to maintain oxygen level and temperature sufficient to sustain fish.

Adequate area to process fish samples and store necessary field equipment.

Constructed with operator and worker safety of primary concern.

Application

EF has many applications including, but not limited to, population sampling, gathering fish for transplanting, salvaging fish or capturing fish (suckers, carp, etc.) to be removed from the water. LMB and SMB populations are not adequately assessed unless EF is used to capture these structure-oriented species. EF has been used effectively to capture small WAE in Grayrocks and Hawk Springs Reservoirs to obtain bony structures for age and growth data and for oxytetracycline (OTC) marking analysis when other techniques failed.

As with other tools, EF is useful for obtaining length and weight data and for collecting fish for disease, genetic or aging structure samples. Estimates of relative abundance, size structure, year class strength, and species composition for many fish species can be obtained through analysis of EF data. Catch Per Unit of Effort (CPUE) is used to compute catch data that are expressed in number of fish per electrofishing hour.

Effort

Depending on water size, 2-4 predetermined stations with varying habitat types should be electrofished for a predetermined period of time, usually 30 minutes. Table 1 details the required electrofishing effort for different size waters. Direction of travel is optional but should be consistent year to year. Start and stop locations should be recorded using GPS.

Table 1. Required boat electrofishing time for waters of varying size.

Water size in surface acres	Number of stations	Sampling time per station (in minutes)
<500	2	30
500-2,500	3	30
> 2,500	4	30

If it becomes necessary to process fish during the 30 minute time period, the elapsed time should be noted, fish processed and distributed within the sampled section of the station. Then, starting at the point along the shoreline where it became necessary to process fish, continue electrofishing for the remainder of the time until the entire 30 minute time period has elapsed.

Sampling should be done at a time of year when target species are expected to be most vulnerable and variability in catch is least. When possible, EF should be conducted when the standardized netting survey is done. However, electrofishing for some species (LMB or SMB) is most effective in the spring. Care should be taken to avoid EF sampling immediately after the passage of a cold front that tends to cool shallow waters.

Electrofishing is not effective in waters exhibiting very high or very low conductivities. Reynolds (1996) offers advice regarding effective electrofishing amperage levels. He also suggests that alterations in generator capacity and electrode design offer the most promise for enhancing EF performance.

<u>Special Considerations</u>

Due to the potential danger of associating water and electricity, all efforts must be taken to ensure the safety of boat operators and netters. Safety measures described in the training course “Principles and Techniques of Electrofishing” offered by the U.S. Fish and Wildlife Service should be followed at all times as directed in the Wyoming Game And Fish Commission Policy Manual (2002).

Electrofishing boats should be large enough to sufficiently handle rough water during sampling events.

Trotline
(TL)

Trot lines (TL), also called set lines, are widely used by commercial fisherman but their application in fish management has been limited (Hubert 1996). TLs are most effective for sampling BLB, CCF, and FLC but will occasionally capture non-target species (e.g., trout, WAE, and CRP). TLs can be effective in both rivers and reservoirs. In rivers, hoop nets and electrofishing typically sample more catfish than TLs (Arteburn 2001). However, TLs will often catch larger fish (Vokoun 1999). In reservoirs, TLs will often catch more and larger fish than trap nets or electrofishing. During late summer and fall TLs are frequently less effective than FGs when catfish may move to open water areas where they prey on small pelagic forage fish. TLs have not been widely used in Wyoming but have proven to be a useful sampling device in the Cody and Casper regions to enhance the catch of CCF.

Specifications:

TLs consist of a heavy main line with droppers or "stagings" placed at four foot intervals along the main line. TLs will have at least 25 ft of hook-free line on either end so that anchors can be secured. Dropper lines should be 12 to 15 in in length and attached to the main line by a barrel swivel to prevent line twisting. Hooks should be plain shanked, ringed eye, and stainless steel or bronze in size 1/0 or 2/0 for adult fish. All hooks should be baited with cut carp, sucker, or other nongame fish species. Bait should be filleted, scales removed, and sliced into approximately one-inch cubes. Although other baits (e.g., crayfish and live minnows) are effective, only cut bait should be used for standardized sampling.

TL Assembly:

Main line should be at least 285 lb test braided nylon twine (treated to prevent rotting).
Main line length will be 250 ft for a 50 hook line and 150 ft for a 25 hook line.
Minimum of 25 ft on each end for shoreline and/or anchor attachment.
90-100 lb test braided nylon twine for droppers.
Droppers to be 12-15 in in length.
Droppers to be placed four ft apart and attached to the line with a barrel swivel.
Each barrel swivel secured in place with a knot on either side of the swivel.
1/0 or 2/0 stainless steel hooks.

Most commercial fishing supply companies sell all the materials needed to construct a TL. These companies also sell complete TLs. When purchasing a finished TL (recommended) ensure that it meets the specifications above.

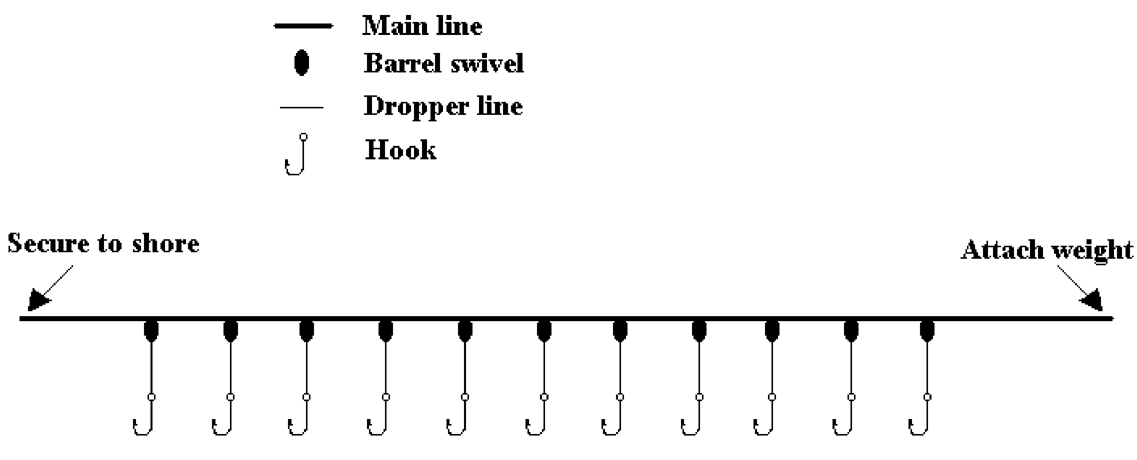
Application

TLs target catfish species and are useful for gathering length and weight data and to collect disease and genetic samples and bony structures for aging. Analysis of TL data yields estimates of relative abundance, size structure, year class strength, and species composition for catfish populations. Catch data are computed using Catch Per Unit Effort (CPUE) and should be expressed in number of fish per hook hour. Example: if two 50-hook TLs are set overnight for 10 hours and yield 50 catfish, CPUE would be 0.050.

Because catfish are crepuscular and nocturnal, TLs should be set at dusk and checked early in the morning for maximum effectiveness. This will prevent "bait stealing" by smaller fishes (e.g., YEP, STC, and sunfish) and minimize the catch of non-target species. TLs will capture fish during daylight hours but generally the rate of catch will be lower. If catch rate is not the primary purpose for sampling, TLs can be fished during the day.

The best locations to set TLs are in shallow water areas (<10 ft), like the upper end of a cove (reservoir) or a mud flat on the inside of a bend (river). TLs can be either floating or sinking. However, sinking lines are recommended to minimize contact with floating debris and recreational boaters, either of which can damage lines and reduce effectiveness. TLs should be set perpendicular to the shoreline (Arizona set). The line can be tied off to the bank (trees, logs, or boulders) or weights (> 20 lb) can be used on both ends to secure the line in position. Highly visible (fluorescent) floats should be attached at both ends to help biologists easily locate the lines and mark the lines for recreational boaters and swimmers. Floats should be clearly labeled as belonging to WGFD. GPS coordinates should be saved or recorded for ease of location upon line retrieval and for site replication. This is particularly helpful when different biologists set and retrieve lines.

TL data forms should include set and retrieved date and time, hours set, location, number of hooks, weather conditions, and names of workers (use Wyoming Data Sheet - Standing Waters). Data should be kept separate for each TL and, at a minimum, the number of catfish captured must be recorded for each TL. All raw data should be entered into the Lakestn database.



Stylized illustration of a trot line.

Effort

Since TLs are used specifically to catch catfish, they provide additional opportunity to target that family of fishes. Where the number of catfish collected using traditional reservoir sampling gears (FG, EG, TN) is insufficient to address the specific data needs of the survey, TLs can be used. Twenty-five hook lines will be used in ponds and 50 hook lines will be used in larger lakes and reservoirs. In most waters four to five overnight TLs sets can easily be processed in one day. To provide consistent catch per effort data, a minimum of three nights of 4-5 TL sets per night should be set to collect sufficient data on larger waters (i.e. greater than 500 surface acres). Smaller waters (i.e., <500 surface acres) can be effectively sampled in 1-2 nights. In either case, we advise biologists to avoid sampling during full moon periods, during and immediately after the passage of a cold front, and during other times of unsettled weather or inflow events which may dramatically alter fish behavior and movement patterns.

TL locations and sampling dates should be standardized for optimal trend data. Reservoirs which experience severe annual fluctuations present challenges that must be dealt with on a water-by-water basis. To establish baseline data, TLs sampling should be conducted for at least three years. Thereafter, the biologist must determine the frequency of sampling necessary to monitor the population. Fish kills, forage shifts, or severe drought conditions may necessitate more frequent sampling to determine impacts to the population.

Special Considerations

TLs require caution when setting and pulling. TLs should not be set or pulled during periods of high wind or strong current (inflow regions). Use care and caution when pulling and setting TLs to prevent hooking injuries.

Although TLs employ a hook and line approach, they are not legal for anglers in Wyoming. Therefore, news releases and individual conversations with anglers are advised to explain the need for this type of sampling. The local game warden should be notified before trot lines are set since they may trigger calls of concern from the public.

During times and in areas of suspected night recreational boat use, TLs should be marked with light reflective floats.

For maximum effectiveness, TLs should be set during the new moon to first quarter period. The lowest catch rates will invariably occur during a full moon.

For maximum effectiveness, TLs should not be set for at least 48 hours after the passage of a cold front.

Pliers are useful for removing fish and for reshaping hooks.

Water Chemistry

Water chemistry analyses are used to evaluate water quality, productivity, or pollution. A wide array of testing procedures have been developed for many organic and inorganic compounds and elements, but generally only a few are of interest to field fisheries biologists. Comprehensive descriptions of compounds along with relevant testing procedures are available in Standard Methods for the Examination of Water and Wastewater (1998).

The Hach Company has developed many water testing kits which offer simple and rapid procedures for most of the compounds of interest to field biologists. The kits include the glassware, reagents, titrants, and instructions needed to perform analyses in the field. Samples which require laboratory analyses using specialized equipment or procedures should be preserved using methods recommended by the laboratory performing the analyses.

It is imperative that clean glassware be used for all water collections to prevent contamination. Rinse glassware with distilled water or sample water. Surface water is commonly used for recreational or drinking water sampling, but fisheries biologists often require samples from various depths to assess conditions at depth strata inhabited by fish. Several designs for water sampling at discrete depths have been developed which differ in size, construction, closing devise, and general design. The Kemmerer water bottle is the most often used sampler in Wyoming. Each Regional fishery management crew should maintain a Kemmerer sampler in good repair.

One sample of water will not be representative of a sizeable lake or reservoir; therefore, samples must be taken at various locations. Standard sites should be established for water chemistry sampling programs.

<u>Alkalinity</u>

The alkalinity of water is its capacity to shift pH to the alkaline side of neutrality or, more specifically, the capacity of water to accept protons, thereby buffering pH shifts. Alkalinity is usually imparted by the bicarbonate, carbonate and hydroxide components in water and is typically expressed as calcium carbonate. Alkalinity is determined by titrating a water sample with a standard solution of strong acid. The end point for carbonate alkalinity is pH 8.3 for carbonate and pH 4.5 for bicarbonate alkalinity (Lind 1985). Total alkalinity is the sum of carbonate and bicarbonate alkalinity. Total alkalinity in nature should range between 20-200 mg $CaCO_3$/L. Waters that become easily acidified from acid rain or other acidic pollution have low alkalinity (<25 mg Ca CO_3/L). Alkalinity should be measured following instructions supplied with the sample kit.

<u>Dissolved Oxygen (DO)</u>

Adequate dissolved oxygen (DO) is necessary for the life of fish and other aquatic organisms. DO content is dependent on the physical, chemical and biochemical activities prevailing in the water body and is greatly influenced by temperature, wind, photosynthesis, respiration, and the diffusion gradient from the atmosphere.

DO may be very low or absent in the hypolimnion or stagnant deep water of eutrophic lakes and reservoirs during the summer months because of decomposition of organic matter. During winter, oxygen may be depleted near the bottom while sufficient photosynthesis occurs near the surface under ice to sustain adequate DO levels. However, heavy snow cover may interfere with light penetration sufficiently to inhibit oxygen at all levels, resulting in winterkill.

Generally, DO less than 3.0 ppm (mg/l) is stressful to fish and many other aquatic organisms. DO levels near 1.0 ppm are lethal to most fish. Concentrations between 3.0 and 5.0 ppm may reduce growth or lower survival in early life stages. Fish species with high metabolic rates are generally less tolerant of low DO.

Water can also become supersaturated with oxygen. Eutrophic reservoirs can produce super saturated oxygen concentrations during periods of bright sunlight through extraordinarily high levels of photosynthesis. DO normally ranges between 1 and 20 ppm in most Wyoming waters. Saturation ranges between 6 and 12 ppm.

DO vertical profiles are most easily acquired using an electronic meter but, when necessary, can also be obtained using a Hach test kit and a Kemmerer sampler. To develop a DO profile, measure DO concentration at 10 ft depth increments from surface to bottom. A profile in the lower, mid and upper reservoir regions is helpful for determining productivity differences within the reservoir. The DO range at a site is determined by measuring DO during midday and before dawn.

Hardness

Hardness is the measure of calcium and magnesium ions in water and is expressed as mg $CaCO_3$/L (Lind 1985). The hardness of water will normally be equal to or less than total alkalinity. Water hardness of less than 60 is considered soft. Hard water contains ions necessary for plant and animal growth. Hardness should be measured following instructions supplied with the sample kit.

pH

The pH of water is the measure of its hydrogen ion activity. Because pH is the logarithm of the reciprocal of the hydrogen ion concentration, a pH change of 1.0 is 10 times more ionic concentration and 2.0 is 100 times more concentrated (Lind 1985). The pH scale ranges from 1 to 14. Neutral water exhibits pH of 7.0 while acidic water has pH lower than 7.0. Most waters range between pH 6.7 to 8.2 (Piper et al 1982). Near pH 10, ammonia can become a problem for fish especially in warm water temperatures. Pens and meters are available for measuring pH. Calibration should be performed following the instructions supplied with the meter.

Temperature

Handheld pocket thermometers can be used at the surface or in shallow water. An electronic temperature meter with a 50 to 100 ft cord is used to measure temperature profiles in standing water. Automatic temperature loggers are available to measure diel fluctuations in temperature over a specific time period.

Total Dissolved Solids

Dissolved solids refer to any minerals, salts, metals, cations or anions dissolved in water and includes anything present in water other than the pure water (H_2O) molecule and suspended solids. Thus, TDS is related to hardness. In the laboratory, TDS is measured by weighing the salts remaining after oven drying a water sample. Microprocessor-based test devices are available for testing TDS in the field. TDS is a key component of the Morphoedaphic Index, used to measure fishery potential.

Turbidity

Turbidity is a measure of water clarity and is influenced by the type and amount of suspended solids present in the water. Light transmission is reduced through absorption or scattering from the suspended solids. Turbidity can be measured using a turbidity meter by pouring a sample of water in the tube supplied with the meter. Calibration of the meter should be done prior to use following instructions supplied with the meter.

Water transparency can be measured using a Secchi disk, which provides a relative measure of turbidity. Secchi disk visibility is influenced by cloud cover and time of day and controllable factors including sunglasses and boat shadow. The Secchi disk should be viewed from the lee side of the boat with the sun to the observers back. To measure light transmission, lower a Secchi disk until it is no longer visible and record the depth. Lower the disk beyond visibility and record the depth at which it becomes visible while retrieving. The average of these two depths is the Secchi depth (Lind 1985).

Zooplankton

(ZPR)

Zooplankton comprises the principal forage for many Wyoming fish species, particularly during early life stages. In standing waters, zooplankton often comprises the mainstay diet of salmonids throughout their lives. Availability and abundance of zooplankton can be integral to the growth, condition, and survival of important trout fisheries. Competition for zooplankton has been shown to limit trout production in some standing waters in Wyoming.

The zooplankton ratio (ZPR) was developed in the early 1990s to assess zooplankton density and to help fisheries managers determine the likelihood that competition limits trout production (Yule 1993). ZPR offers a simple and rapid tool to assess the availability of zooplankton of preferred size for trout. ZPR is a volumetric measurement whereby organisms are live sieved through two different mesh nets (either 153$_{\mu}$ and 500$_{\mu}$ or 500$_{\mu}$ and 750$_{\mu}$) in the field and animals of different size are later settled in graduated cylinders. The derived ratios provide indices of zooplankton size structure. Each regional fisheries management crew should maintain a set of zooplankton nets in good repair.

Monitoring of zooplankton through volumetric measurement is relatively simple and analysis can be done without a lab or specialized equipment beyond the collection nets. Supplies needed are two or three zooplankton nets of different mesh size, rope, weights, alcohol, rinse bottles, sample containers, hose clamps, graduated cylinder(s), and a screwdriver to disconnect collection cup from the zooplankton net.

Specifications:

Zooplankton Nets:

Conical shaped.
Hoop diameter = 0.5 m.
Height = 1.5 m.
Detachable collection cup.

Recommended Mesh Sizes:
- 153 micron.
- 500 micron.
- 750 micron.

Field and laboratory equipment:

Alcohol.
Plastic rinse bottles.
Sample containers.
Graduated cylinders.

Application

Zooplankton sampling is particularly useful for determining the suitability of large waters for stocking or for evaluating existing stocking programs. Decisions about appropriate stocking densities can be better made with knowledge about zooplankton abundance and size structure.

Zooplankton net mesh sizes should be selected based on the size of zooplankton consumed by fish. For example, Daphnia consumed by RBT in Alcova ranged from 1.4 to 2.7 mm (Yule 1993). Zooplankton that RBT prefer (> 1.0 mm) can be sampled with 500$_{\mu}$ mesh. Waters with large zooplankton should be sampled with 500µ and 750µ mesh nets. The 153µ and 500µ mesh nets should be used for waters with smaller zooplankton. Productive waters typically have ZPR greater than 0.6 and can support relatively high stocking density. ZPR less than 0.25 indicates unproductive waters or suggests overgrazing.

Method

Each sampling net is set up with a weight attached to the collection cup and a rope attached to the top of the net. The rope is marked for the desired depth by tying a knot or marking it with a permanent marker. Lowering the net slowly for the last few feet prevents agitation of bottom sediments in shallow waters. The net is raised at a slow but constant rate to prevent upwelling of the sample. The contents should be flushed from the net into the sample cup before lifting the net from the water by splashing water on the net while lifting. If algae are abundant in the sample leave approximately 50 ml of water in the sample prior to adding the alcohol (Yule 1993). The jar contents are poured into a container. The plastic rinse bottled is used to force contents from the jar into the sample container, which is then preserved with alcohol. Each container must be labeled to identify the sample by water name, location, mesh size, and date.

Ratios are determined by pouring each sample into a separate graduated cylinder, which are then allowed to settle. A 100 ml graduated cylinder may be required for productive waters while a 10 or 25 ml graduated cylinder works well for less productive samples. Cylinders should not be agitated during settling. Zooplankton volume is measured to the nearest ml. Algae can be decanted before pouring the samples into graduated cylinders following a two-week waiting period (Yule 1993). Measurements should be recorded on the Zooplankton Data Entry Sheet. An example form is available for duplication in Appendix I. ZPR is calculated by dividing the volume of the sample from the larger mesh by the sample from the smaller mesh. ZPR is normally less than 1.

There is currently no database for entering and reporting zooplankton information. The Lakestn database should be modified to include a table for reporting zooplankton information.

Effort

Four sample sites should be selected for monitoring programs. Optimally, the sample sites should be taken from each of four quadrants of the water (Galbraith and Schneider 2000). Replicate samples should be taken with each zooplankton net from each site. A total of 16 samples is recommended (eight samples per mesh size). Sample sites should be located near the mid-region of the reservoir to minimize variation that may occur in zooplankton abundance between upper and lower reservoir regions (Yule 1993).

Sampling depth of 60 ft is recommended to ensure zooplankton production is consistently measured. In waters where depth is less than 60 ft, samples should be taken as deep as possible to sample zooplankton production without encountering bottom sediment. Zooplankton presence can generally be determined by measuring DO since zooplankton will not be found in anoxic water. Sample depth should remain the same between sites.

Special Considerations

Zooplankton sampling can be used to determine availability of zooplankton for forage fish and YOY fishes.

Tows of 20 ft or 40 ft in addition to the 60 ft tows can help determine depths where zooplankton densities are highest.

CHAPTER 3 -- FISHERY STATISTICS

Catch per Unit Effort
(CPUE)

Catch per unit effort (CPUE) can be used as an index to population density under the assumption that CPUE is proportional to stock density (Hubert 1996). Thus, changes in CPUE should reflect corresponding changes in species abundance. More specifically, CPUE is defined as "the number or weight of organisms captured with a defined unit of sampling effort" (Murphy and Willis 1996) and can be derived from active or passive sampling gear.

CPUE is one of the most common statistics used in the assessment and management of fisheries. It is commonly related to indices of condition, growth, length structure and other biological statistics (see Murphy and Willis 1996 and Ney 1999). Unfortunately, CPUE is influenced by many factors other than density of the target species including fish behavior, weather, water levels, season, and water temperature (Pristas and Trent 1977; Bettross and Willis 1988; Guy and Willis 1991; Mero and Willis 1992; Hayes et al. 1996). The influence of these confounding factors can be kept to a minimum by standardizing sampling gear and methodology (Fisheries Techniques Standardization Committee 1992). Changes in CPUE are more likely to reflect changes in population density if biologists adhere to strict sampling regimes (Hubert 1996).

Selection of minimum sample sizes for the calculation of gill net CPUE is a highly subjective process, as decisions have to be made based upon logistical constraints and the desired precision in the estimate and statistical power to detect change. For example, power analysis of 2001 FG data from Pathfinder Reservoir indicates that 170 FG would need to be set to detect a 10% change in RBT CPUE at $\alpha = 0.10$. Conversely, the 12 FG set in 2001 in Pathfinder Reservoir only allow the detection of changes in RBT CPUE which are greater than 40% of the mean at $\alpha = 0.10$.

The accuracy and precision of CPUE, and thus the interpretive utility, are profoundly affected by its inherent variability and by logistical constraints which limit sample size. Other commitments typically prevent management crews from devoting more than one week to the sampling of a particular fishery in any given year. This manual recommends that the number of EG and FG set per night be limited to three and four, respectively, because of time required to retrieve nets, process fish, and travel to net locations. Thus, in one week of sampling it should be possible to process 12 EG and 16 FG (see FG and EG Summaries). The sampling methodologies outlined for FG and EG were designed to minimize CPUE variance within these logistical constraints. Table 1 describes the degree of change biologists should be able to detect in CPUE of RBT and WAE sampled with 16 FG and 12 EG, respectively, from Alcova, Pathfinder, and Seminoe Reservoirs at various levels of confidence.

Table 1. Degree of change (%) biologists can expect to detect in CPUE of RBT from 16 FG and WAE from 12 EG in Alcova, Pathfinder, and Seminoe reservoirs at various levels of confidence.

	Alpha (α)		
	0.20	0.10	0.05
16 FG	25%	33%	125%
12 EG	20%	25%	80%

Special Considerations

Gill net CPUE should be calculated for each net, then averaged. This allows variance to be estimated for CPUE.

CPUE is an important and useful fisheries statistic even though it is inherently variable. Given this variability, the development of management goals and objectives based solely upon CPUE is cautioned. It is crucial to use CPUE in conjunction with other fisheries statistics (age and growth, condition, length structure, etc.) to avoid misinterpretation.

Length Frequency

Age and growth analyses can be accomplished using known aged populations, examining bony structures, or analyzing peaks on length frequency histograms (Everhart 1953, Devries and Frie 1996). Known aged populations are rare and typically unavailable to Wyoming fisheries biologists. The accuracy and precision obtained when using bony structures for aging and growth measurements often support their use for research and management applications. However, aging with bony structures can be tedious and time consuming, and such precision may not always be necessary to achieve sampling objectives. In many instances, the simple use of properly collected length frequency data can provide adequate information with which population trends can be assessed or upon which management decisions can be based. Length frequency histograms can also be valuable public relations tools.

Length frequency distributions have been used to estimate the age of fish for over a century. As Everhart (1953) noted, the method depends on the fact that the length of fish of each age tend to form a normal distribution. Age, then, is determined by the peaks which form on a histogram. At least two considerations advise cautionary use of length frequency distribution data to properly assess cohort strengths. First, the sample population must adequately characterize the size structure of fish populating the water. Ney (1993) states that the sample represents the population size structure when all ages or sizes of a species are taken in proportion to their true abundance. Second, length frequency distributions often do not adequately define older aged fish since length frequency peaks commonly overlap as fish attain larger size. Overlap results from the relatively slow growth of older fish and the subsequent increased dispersion in the size of older fish.

A proper sample of the population is required to obtain reliable length frequency information. Length data in standing waters is most often collected with gill nets. The gill net specifications outlined within this manual have been established to collect a representative sample of adult fish. When measuring fish removed from gill nets to obtain length frequency data, all fish of each species of interest must be measured to minimize bias within size groups. It is inappropriate to measure a sample within each size group, as is suggested for relative weight calculations or when using bony structures to age fish.

The use of length frequency distribution to assess cohort strength is typically only valid for the first several year classes. Graphically illustrating length distributions in histograms often highlights the size at which growth overlap begins to occur. Once overlap in growth begins, length frequency data cannot be used to accurately determine fish age. However, when peaks are very apparent, logical inferences about age and growth of fish are usually valid.

Fish behavior and environmental influences may further confuse the use of length frequency data. Fish of a certain size may tend to concentrate, increasing or decreasing their exposure to sampling gear and to capture. Different hatching periods within a year might cause different length peaks within the same aged fish. Within water environmental differences may result in varied growth within one age group. Although these concerns do not invalidate the use of length frequency information, biologists should be aware of the limitations and note potential factors which might influence sample effectiveness and/or fish growth.

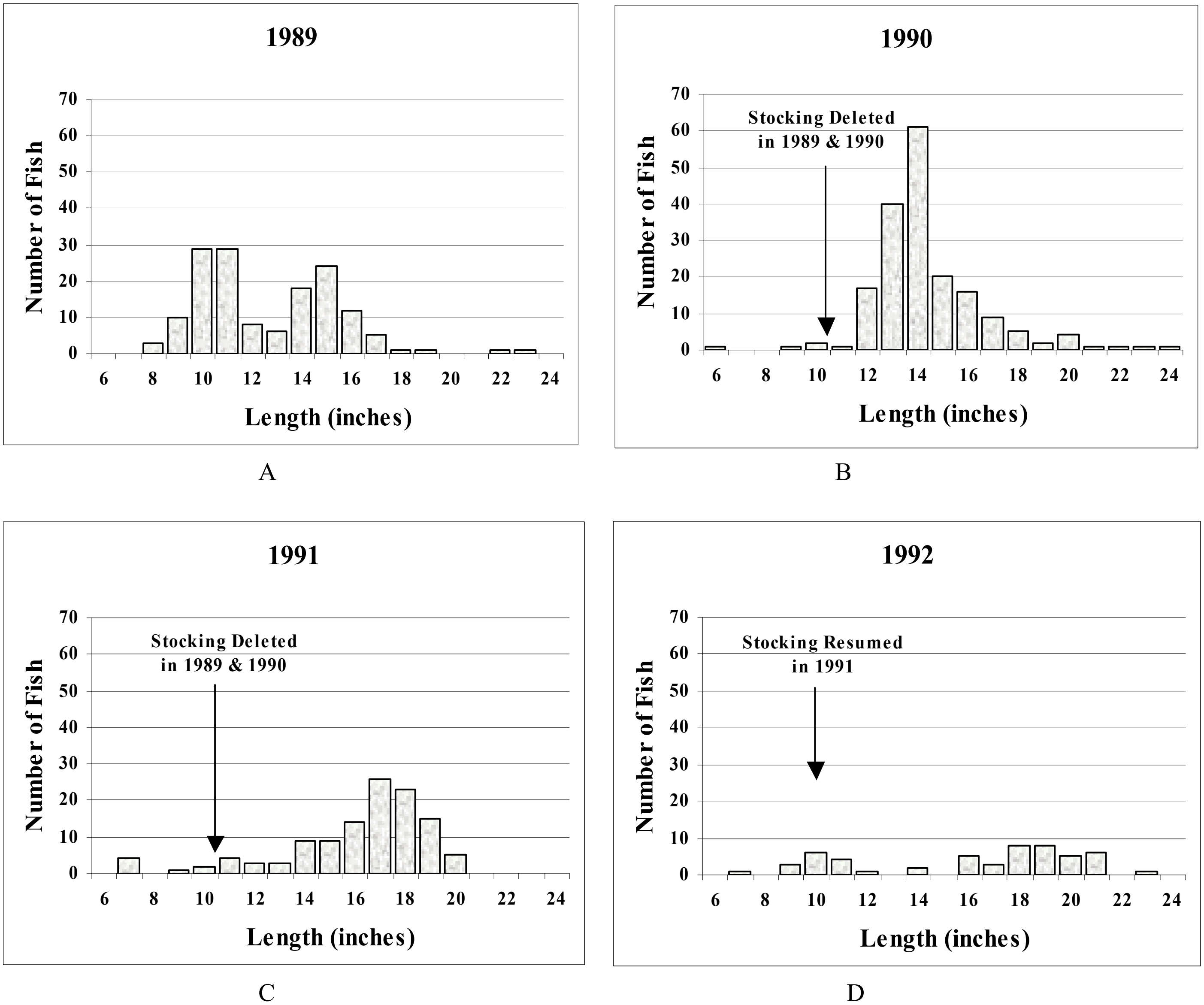
Length frequency data are particularly valuable when highlighting strong and weak year classes. These data are often the most useful when illustrating age classes and growth rates to the public. Histograms are informative and easily understood by nonprofessionals. Examining length histograms is rapid and simple. Data used when graphing length frequency distributions is routinely collected during most fish surveys and fish do not need to be sacrificed.

To illustrate the potential value of length frequency data, we present the response of a Wyoming WAE population to a change in stocking over a four year period. From the initial filling of Grayrocks Reservoir in 1982 through 1988 WAE fry were stocked annually in the spring. To evaluate the contribution of fry stocking to WAE recruitment in Grayrocks Reservoir, stocking was deleted for two consecutive years, 1989 and 1990. The reaction of the WAE population was readily apparent from length frequency distributions graphed each year following September gill net sampling. Figure 1 A shows the occurrence of a strong cohort of yearling fish ranging in length from 8-11 inches. Virtually no recruitment of fish into the yearling cohort was evident in either 1990 or 1991 (Figures 1 B & C). Stocking was resumed in spring 1991and by 1992 recruitment of yearling fish was apparent (Figure 1 D). Also apparent was the overall increase in WAE size as few young fish entered the fishery for two consecutive years. Graphs similar to these were used to help convince concerned anglers that more restrictive regulations were not the proper management tool to address the deficit of young fish in Grayrocks Reservoir after a petition attempting to force action was received by the WGFD.

Application

Record total length of all fish of yearling and older size for all species of interest to the nearest 0.1 in.

Histogram design should follow the format outlined in “Reporting”.



A B C D

Figure 1 A-D. Length frequency histograms of WAE captured in sinking experimental gill nets from Grayrocks Reservoir, September 1989, 1990, 1991, and 1992.

Length Structure
(PSD AND RSD)

Stock density indices such as proportional stock density (PSD) and relative stock density (RSD) quantify length frequency data for fish populations (Willis et al. 1993). Stock density indices were introduced in the 1970s and, by 1985, 34 states reported using PSD or RSD to describe the length structure of at least one species of fish (Gabelhouse et al. 1992). Stock density indices were developed on warmwater bass and panfish fisheries. As with other assessment tools such as the relative weight (Wr) index that were first applied to warmwater fisheries, adoption of stock density indices by managers of coldwater fisheries has been slow. For example, only six states reported using PSD/RSD for the assessment of coldwater fisheries in 1985 (Gabelhouse et al. 1992). Stock density indices have been used only sporadically by Wyoming fisheries biologists. However, a growing body of research indicates that stock density indices may be an equally useful tool for the assessment and management of coldwater fisheries (Johnson et al. 1992; Chamberlain 1993; Bailey 2001).

PSD (Anderson 1976) is defined as the proportion of stock length fish that are greater than or equal to quality length. Anderson and Weithman (1978) defined stock and quality lengths for individual species based upon percentages of the all tackle world record length for that species.

Gabelhouse (1984) observed that PSD is often not sensitive enough because length structures of fish populations with similar PSD can vary greatly. For example, Seminoe and Glendo reservoirs have WAE populations with similar values of PSD (43 and 45 respectively) but Figure 1 reveals that these WAE populations have prominent differences in length structure. Seminoe Reservoir has a substantial portion of its WAE population composed of fish greater than 20 inches in length with a small number of individuals surpassing 30 inches in length. However, WAE greater than 20 inches in total length compose a very small portion of the Glendo Reservoir WAE population and no individuals exceed 30 inches in length. Observations like these prompted Gabelhouse (1984) to further develop RSD.

RSD describes length structure among three added length categories in addition to the stock and quality categories used in PSD. Gabelhouse (1984) proposed length categories for 35 warm and coolwater species. They are presented at the end of this section. Length categories were defined in Gabelhouse (1984) as:

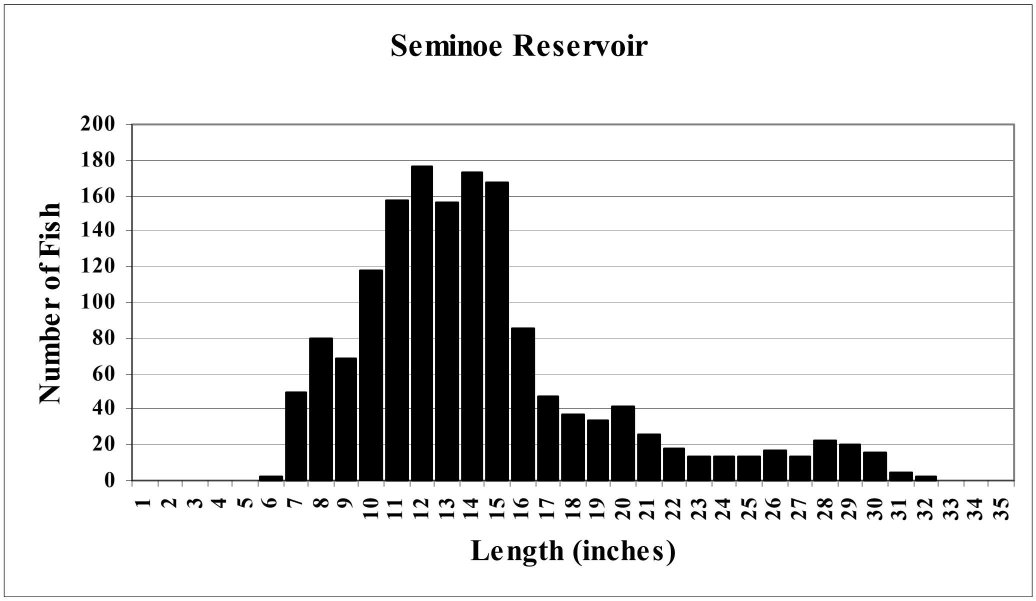
Stock (S): 20-26% of world record length; variously defined as the approximate length at maturity, minimum length that provides recreational value, minimum length effectively sampled by traditional sampling gear.

Quality (Q): 36-41% of world record length; size of fish that most anglers like to catch.

Preferred (P): 45-55% of world record length; size of fish that most anglers prefer to catch.

Memorable (M): 59-64% of world record length; size of fish that most anglers remember catching.

Trophy (T): 74-80% of world record length; size of fish worthy of acknowledgement.



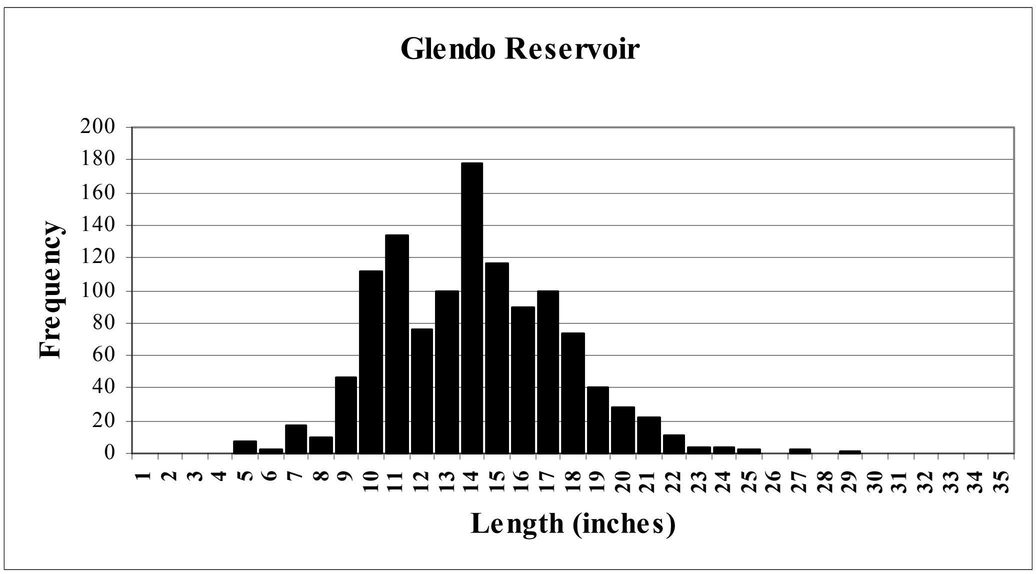


Figure 1. Length-frequency histograms for WAE from Seminoe and Glendo reservoirs.

There are two approaches to RSD: traditional and incremental. Willis et al. (1993) defined traditional RSD as "…the percentages of stock length fish that also are longer than the defined minimum lengths for size categories" and incremental RSD as "…the percentage of stock length fish consisting of individuals between the minimum lengths for size categories". Gabelhouse (1984) provided advice on when each approach should be used. Incremental RSD should be used when biologists wish to assess fish population changes, such as year class strength, for a single water body or wish to assess the effects of a similar treatment to multiple fish populations. Traditional RSD should be used when general comparisons are made between water bodies as it lessens the effects of weak or missing age groups. Given the erratic recruitment most self-sustaining fish populations exhibit in Wyoming's large standing waters, the traditional approach to RSD is recommended for the purpose of this manual. Traditional RSD is unitless, expressed as a whole number, and is calculated as:

$$RSD = 100(L/S)$$

where: RSD = traditional relative stock density, L = number of fish greater than or equal to a specified length (quality, preferred, memorable, or trophy), and S = number of fish greater than or equal to stock length.

Table 1 demonstrates the usefulness of traditional RSD. Seminoe and Glendo reservoirs have similar PSD, however, traditional RSD clarifies and highlights the differences in the length structure of these WAE populations (Figure 1). Although PSD is useful, RSD should be used to describe length structure of Wyoming fish populations due to these advantages.

Table 1. Proportional stock density (PSD) and traditional relative stock density (RSD) for WAE from Seminoe and Glendo reservoirs. Minimum stock (S), quality (Q), preferred (P), memorable (M), and trophy (T) lengths for WAE are defined as 10, 15, 20, 25, and 30 inches respectively.

	Seminoe	Glendo
PSD	43	45
RSD-Q	43	45
RSD-P	16	7
RSD-M	8	1
RSD-T	2	0

At a minimum, RSD can be used to quantify length-frequency data, to facilitate communication between biologists and comparisons between fish populations, and to set measurable management objectives for both wild fisheries and those maintained through stocking. RSD may also provide additional insight on population dynamics such as recruitment, growth, and mortality (see Willis et al. 1993).

Sample sizes of 100 or more fish are usually large enough to detect modest differences (5 to 10 points) in RSD at $\alpha = 0.10$ (Gustafson 1988). The sampling methodology outlined in this manual typically yields sufficient sample sizes to generate RSD statistics for the primary species of management concern.

Special Considerations

Length structure of sport fish populations should be described using traditional RSD due to the inconsistent recruitment experienced by most self-sustaining fish populations in Wyoming's standing waters. Traditional RSD lessens the effects of year class strength.

RSD provides a useful tool for describing the length structure of fish populations. However, the factors producing a given length structure can be extremely varied. RSD must be used in conjunction with other fisheries statistics (CPUE, relative weight, age structure, growth, etc.) to avoid misinterpretation.

Proposed length categories for 35 warm and coolwater species (Gabelhouse 1984) (E=English; M=Metric).

Species	Stock		Quality		Preferred		Memorable		Trophy		Source
	E	M	E	M	E	M	E	M	E	M	
Arctic grayling	8	20	12	30	16	40	20	50	22	55	Hyatt (2000)
Black bullhead	6	15	9	23	12	30	15	38	18	46	Gabelhouse (1984)
Black crappie	5	13	8	20	10	25	12	30	15	38	Gabelhouse (1984)
Bluegill	3	8	6	15	8	20	10	25	12	30	Gabelhouse (1984)
Brook trout	8	20	12	30	16	40	20	50	24	60	Hyatt (2000)
Brown trout (lentic)	8	20	12	30	16	40	20	50	24	60	Hyatt (2000)
Brown trout (lotic)	6	15	9	23	12	30	15	38	18	46	Milewski & Brown (1994)
Burbot	8	20	15	38	21	53	26	67	32	82	Fisher et al. (1996)
Channel catfish	11	28	16	41	24	61	28	71	36	91	Gabelhouse (1984)
Common carp	11	28	16	41	21	53	26	66	33	84	Gabelhouse (1984)
Cutthroat trout	8	20	14	35	18	45	24	60	30	75	Kruse & Hubert (1997)
Flathead catfish	14	35	20	51	28	71	34	86	40	102	Quinn (1991)
Freshwater drum	8	20	12	30	15	38	20	51	25	63	Gabelhouse (1984)
Gizzard shad	7	18	11	28							Anderson & Gutreuter (1983)
Golden trout	8	20	10	25	14	35	18	45	22	55	Hyatt (2000)
Green sunfish	3	8	6	15	8	20	10	25	12	30	Gabelhouse (1984)
Kokanee	8	20	10	25	12	30	16	40	20	50	Hyatt (2000)
Lake trout	12	30	20	50	26	65	31	80	39	100	Hubert et al. (1994)
Largemouth bass	8	20	12	30	15	38	20	51	25	63	Gabelhouse (1984)
Muskellunge	20	51	30	76	38	97	42	107	50	127	Gabelhouse (1984)
Northern pike	14	35	21	53	28	71	34	86	44	112	Gabelhouse (1984)
Pumpkinseed	3	8	6	15	8	20	10	25	12	30	Gabelhouse (1984)
Rainbow trout	10	25	16	40	20	50	26	65	31	80	Simpkins & Hubert (1996)
Redear sunfish	4	10	7	18	9	23	11	28	13	33	Gabelhouse (1984)
River carpsucker	7	18	11	28	14	36	18	46	22	56	Bister et al. (2000)
Rock bass	4	10	7	18	9	23	11	28	13	33	Gabelhouse (1984)
Sauger	8	20	12	30	15	38	20	51	25	63	Gabelhouse (1984)
Shorthead redhorse	6	15	10	25	13	33	16	41	20	51	Bister et al. (2000)
Smallmouth bass	7	18	11	28	14	35	17	43	20	51	Gabelhouse (1984)
Splake	8	20	10	25	14	35	16	40	22	55	Hyatt (2000)
Walleye	10	25	15	38	20	51	25	63	30	76	Gabelhouse (1984)
Walleye X sauger	9	23	14	35	18	46	22	56	27	69	Flammang et al. (1993)
White crappie	5	13	8	20	10	25	12	30	15	38	Gabelhouse (1984)
White sucker	6	15	10	25	13	33	16	41	20	51	Bister et al. (2000)
Yellow perch	5	13	8	20	10	25	12	30	15	38	Gabelhouse (1984)

Relative Weight
(W_R)

Relative weight (W_r) (Wege and Anderson 1978) provides a comparative measure of fish plumpness (Murphy et al. 1990) and is used as an index to fish body condition. W_r is the ratio of the weight of an individual fish divided by a standard weight for that species and length. The underlying assumption in the W_r index is that fish plumpness is related to physiological well being. W_r has been positively correlated to lipid content and proximate body condition, growth, gamete production and reproductive success, and length structure. W_r has been negatively correlated to population density. Other studies suggest that W_r may serve as an index to prey availability (see Literature Cited).

W_r should be calculated by the method presented by Anderson and Neumann (1996). Standard weight (W_s) equations are listed in Appendix X.

$$\log10(W_s) = a + b(\log10(L))$$
and
$$W_r = 100(W/ W_s)$$

where: W_s = standard weight, a = intercept, b = slope, L = fish length, W_r = relative weight, and W = fish weight.

Condition indices have been widely used in the management of Wyoming's fisheries. Fulton's condition factor (C) was used for many years in Wyoming for the assessment of fish condition. Unfortunately, C has several critical flaws. Most critically, within species comparisons of fish of dissimilar lengths and between species comparisons cannot be made (Murphy et al. 1991). These limitations of C encouraged the development of W_r in the late 1970s. W_r allows comparisons of fish of disparate lengths and of different species. W_s equations were developed via the regression line percentile technique, which results in W_r values of 93 being "average". W_s equations were developed for many warm and coolwater species in the 1980s and early 1990s but were not developed for many coldwater species such as CUT until somewhat recently. The availability of W_s equations for species of interest in Wyoming coupled with the advantages of W_r over C prompted the WGFD to switch from C to W_r in 2000. Those equations are presented at the end of this summary.

Numerous authors have cautioned that fish populations should not be represented with a mean Wr without first testing for relationships between length and W_r (Cone 1989; Murphy et al. 1990; Springer et al. 1990; Murphy et al. 1991; Marwitz and Hubert 1997; Porath and Peters 1997; Hyatt 2000). Representing fish populations with a mean W_r may mask important length related trends in fish condition. For example, WAE in Seminoe Reservoir have a mean W_r of 90.2 (90% C.I. = 0.41). However, analysis of W_r within length categories reveals that a relationship exists between length and W_r for this WAE population (Figure 1). Analysis of W_r by length category provides valuable insight into the factors, such as forage availability for smaller WAE, which are influencing this fishery.

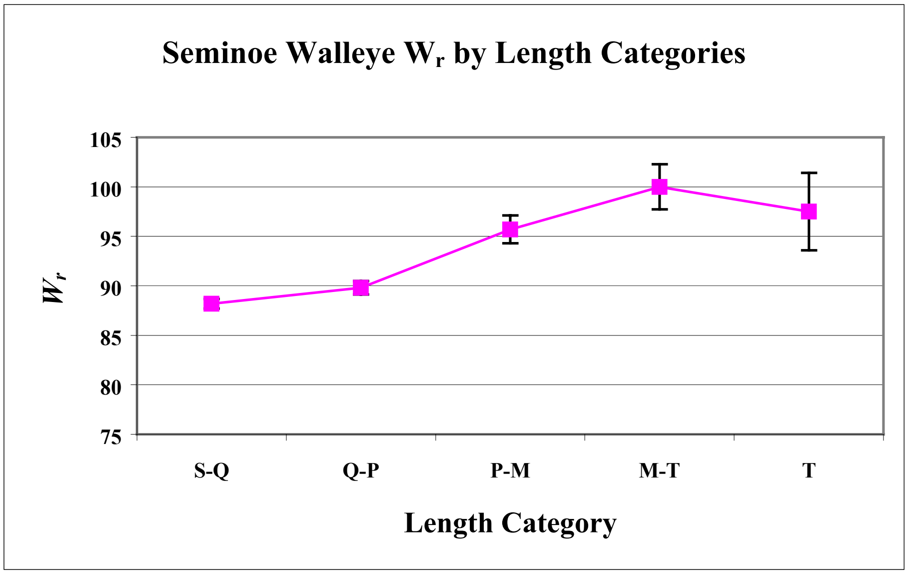


Figure 1. Mean W_r of WAE in Seminoe Reservoir among the length categories described by Gabelhouse (1984). Stock (S), Quality (Q), Preferred (P), Memorable (M), and Trophy (T) represent WAE of 10, 15, 20, 25, and 30 inches respectively. Error bars represent 90% confidence intervals.

Due to the dynamic nature of most fish populations, representing fish populations with a mean W_r, when there are relationships between length and W_r, poses another problem: it will be difficult to determine if changes in W_r are real or are simply an artifact of changes in population length structure. Murphy et al. recommended that mean W_r values be calculated within the length categories defined by Gabelhouse (1984; see Length Structure summary) for the calculation of relative stock density (RSD).

The standard weights produced by the W_s equations should not necessarily be used to represent optimal values for individual fish populations (Murphy et al. 1990). W_r targets should be adjusted relative to the management goals for each particular fishery. Using W_s to represent an optimal value or the creation of a statewide W_r target for Wyoming fish populations would not be any more conducive to effective management than the creation of statewide targets for CPUE and length structure. Biologists should consider how W_r relates to the management goals for a particular fishery and then develop W_r targets that will help achieve the goal for that fishery.

W_r has been shown to be a valuable tool in the assessment and management of fish populations. However, as with most biological statistics, W_r is limited by inherent variability and may be influenced by numerous confounding factors. Thus, W_r should be used in addition to, not in place of, other tools (CPUE, length and age structure, growth, etc.) to effectively manage fish populations. Making management decisions based upon any single fisheries statistic is unwise.

Relatively small changes or differences in W_r (5% change or difference) can be detected with reasonable sample sizes when W_r is assessed by length category (Hyatt 2000). Biologists should be able to detect 5% differences in W_r at $\alpha = 0.10$ with 10-15 fish in a given length category. The sampling methodology outlined in this manual typically yields sufficient sample sizes to generate W_r statistics for the primary species of management concern.

Special Considerations

Atypical values or significant changes in W_r should alert biologists to unusual or changing environmental conditions and should prompt close examination of potential causes. Critically investigating unusual W_r or determining why W_r values support or contradict other fisheries statistics may produce insightful information on population dynamics.

Mean W_r should be calculated within the length categories defined by Gabelhouse (1984) for all game species in order to detect length related trends in W_r and to facilitate comparisons between fish populations.

The Lakestn database should be modified to calculate W_r with length categories defined by Gabelhouse (1984).

Intercepts (a) and slopes (b) for standard weight (W_s) equations that have been proposed for Wyoming fish species. M = metri

Species	Intercept (a) M	E	Slope (b)	Minimum TL	Source
Arctic grayling	-4.929	-3.419	2.966	160	Hyatt 2000
Black bullhead	-4.974	-3.297	3.085	130	Bister et al. (2000)
Black crappie	-5.618	-3.576	3.345	100	Neumann and Murphy (1991)
Bluegill	-5.374	-3.371	3.316	80	Hillman (1982)
Brook trout (lentic)	-5.096	-3.442	3.069	120	Hyatt and Hubert (2001a)
Brook trout (lotic)	-5.212	-3.346	3.110	120	Hyatt and Hubert (2001a)
Brown trout (lentic)	-5.422	-3.592	3.194	140	Hyatt and Hubert (2001b)
Brown trout (lotic)	-4.867	-3.366	2.960	140	Milewski and Brown (1994)
Burbot	-4.868	-3.454	2.898	200	Fisher et al. (1996)
Channel catfish	-5.800	-3.829	3.294	70	Brown et al. (1995)
Common carp	-4.639	-3.194	2.920	200	Bister et al. (2000)
Cutthroat trout (lentic)	-5.192	-3.514	3.086	130	Kruse and Hubert (1997)
Cutthroat trout (lotic)	-5.189	-3.492	3.099	130	Kruse and Hubert (1997)
Flathead catfish	-5.542	-3.661	3.230	130	Bister et al. (2000)
Freshwater drum	-5.419	-3.575	3.204	100	Blackwell et al. (1995)
Gizzard shad	-5.376	-3.580	3.170	180	Anderson and Gutreuter (1983)
Golden shiner	-5.593	-3.611	3.302	50	Laio et al. (1995)
Golden trout	-5.088	-3.473	3.041	120	Hyatt and Hubert (2000)
Green sunfish	-4.915	-3.216	3.101	60	Bister et al. (2000)
Kokanee	-5.062	-3.458	3.033	120	Hyatt and Hubert (2000)
Lake trout	-5.681	-3.778	3.246	280	Piccolo et al. (1993)
Largemouth bass	-5.528	-3.587	3.273	150	Henson (1991)
Mountain whitefish	-5.086	-3.478	3.036	140	Rogers et al. (1996)
Muskellunge	-6.066	-4.052	3.325	380	Neumann and Willis (1994)
Northern pike	-5.437	-3.745	3.096	100	Willis (unpublished)
Pumpkinseed	-5.179	-3.289	3.237	50	Laio et al. (1995)
Rainbow trout (lentic)	-4.898	-3.354	2.990	120	Simpkins and Hubert (1996)
Rainbow trout (lotic)	-5.023	-3.432	3.024	120	Simpkins and Hubert (1996)
Redear sunfish	-4.968	-3.263	3.119	70	Pope et al. (1995)
River carpsucker	-4.839	-3.293	2.992	130	Bister et al. (2000)
Rock bass	-4.827	-3.166	3.074	80	Bister et al. (2000)
Sauger	-5.492	-3.671	3.187	70	Guy (unpublished)
Shorthead redhorse	-4.841	-3.337	2.962	100	Bister et al. (2000)
Shovelnose sturgeon	-6.287	-4.266	3.330	130	Quist et al. (1998)
Smallmouth bass	-5.329	-3.491	3.200	150	Kolander et al. (1993)
Splake	-5.251	-3.556	3.098	130	Hyatt (2000)
Tiger musky	-6.126	-4.095	3.337	240	Rogers and Koupal (unpublished)
Walleye	-5.453	-3.642	3.180	150	Murphy et al. (1990)
Walleye X sauger	-5.692	-3.760	3.266	170	Flammang et al. (1993)
White crappie	-5.642	-3.618	3.332	100	Neumann and Murphy (1991)
White sucker	-4.755	-3.282	2.940	100	Bister et al. (2000)
Yellow perch	-5.386	-3.506	3.230	100	Willis et al. (1991)

Age and Growth

Accurate age and growth information can support or strengthen many key fisheries management decisions (stocking, regulations, forage manipulation). Age and growth data can be used to monitor changes in fish growth and age structure, to determine age frequency, age at maturity, mortality, survival, longevity, and to estimate year class strength (Everhart et al. 1975, Lagler 1956). On a population level, age and growth information is crucial to a realistic assessment of population dynamics (Musker 1985).

Age and growth determinations can be accomplished using known aged populations, analyzing peaks on length frequency histograms, or examining bony structures (Everhart 1953, Devries and Frie 1996). The most common and definitive procedure uses specific bony structures: scales, otoliths, spines, rays, cleithra, vertebrae, opercular bones, and dentary bones (Devries and Frie 1996). In Wyoming, scales, otoliths, and spines are used so we limit this discussion to those structures.

Frequency of Age and Growth Data Collection

Baseline age and growth data should be compiled for primary sport fish species for all major standing waters in Wyoming. Once baseline data are available subsequent age and growth data should be collected when a significant change which may affect growth is anticipated or has occurred in a fishery. As examples, a slot limit is implemented with the goal of growing larger trout or additional forage is introduced to enhance WAE growth.

Given the dynamic nature of WAE fisheries, age and growth data should be collected at least every 5 years to ensure baseline conditions are documented. Particularly for hatchery-maintained salmonid populations, beyond the initial baseline information, there is often no need to collect more age and growth data until a major change is perceived.

Structures to Age

Generally, scales should be collected for age determination since they are usually easy to view and annual marks are readily identified in relatively young fish. For CCF, the left pectoral spine should be taken. For age and growth and back calculations, otoliths and/or spines may be more appropriate (see discussion below). When verification of ages determined from scales is desired, otoliths and/or spines should be collected. Otoliths and spines may be especially useful for slow-growing or long-lived fish since annuli on the outer edge of scales often become indistinguishable on older individuals.

Numbers to Collect

When possible, aging structures should be collected from 10-15 fish per inch group (Schneider 2000). However, when practical collect more aging structures than needed to allow for regenerated scales or otherwise unusable aging structures.

Procedures

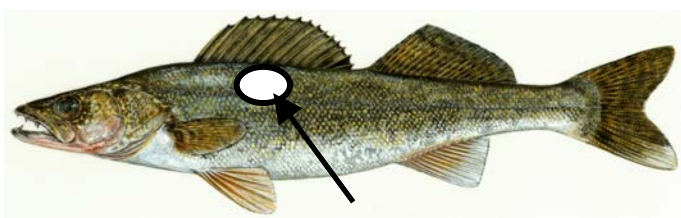
Coin envelopes are used to hold and store scales. Paper inserts can be used to more easily remove scales from the envelopes. Record accurate and complete information on coin envelopes including:

Water Name or WaterID	Species
Collection Date	Length
Collecting Gear	Weight
Collector's Name	Sex (when possible)

Scales

Scales can be used to age non-salmonid fishes. Scales can also be used for age determination of salmonids but readers are cautioned that age may be under-estimated, particularly when growth is slow (Mackay, et al. 1990). Age determination using scales is not recommended where fish of any species routinely live longer than 5 years because of the difficulty associated with identifying outer annuli (Devries and Frie 1996). Scales can be useful for calculating growth of non-salmonids through back-calculation, again with caution because in some species scales, unlike other calcified structures, are not yet formed at hatching (see Age & Growth section). Scales are not used for calculating growth of salmonids.

Age determination is simplified by taking care when collecting scales. Scale samples should be taken from standard areas of the fish. The recommended location for most Wyoming fishes is just above the lateral line and below the middle of the dorsal fin (Devries and Frie 1996) Processing will be simplified if the mucous layer is first scraped away from the spot where scales will be taken. Remove scales with a knife blade and insert them directly into a coin envelope or onto the paper insert. Ensure that the knife blade is cleaned between samples to prevent cross contamination.



Processing Scales

Scales can be pressed onto acetate for ease of reading, storage, and archival. As many scales as practical should be placed on a piece of acetate, shiny side up. Scales should then be sandwiched between two pieces of acetate and pressed with either a jeweler's or heat press. Original scales should be stored with the acetate impressions in the coin envelope. Making as many scale impressions as possible per fish maximizes the chance of obtaining a useable sample. Do not press obviously regenerated, deformed, or torn scales.

Age Determination with Scales

The acetate slide is viewed using a microfiche reader or microscope to magnify the impression. Age is determined by counting complete annuli. Annuli are defined as "a distinguishable zone on a hard structure that separates successive annual growth zones" (Murphy and Willis 1996).

Otoliths

Otoliths require more effort to collect than scales but can be used to reliably evaluate growth as well as age. The largest of the three pairs of otoliths, the sagittae, is preferred for aging (Devries and Frie 1996). Fish must be sacrificed because dissection of the head is required for otolith removal. Two effective methods of extraction are by cutting from the top of the head through the brain and from below through the roof of the mouth between the gill arches (Schlueter 1989, Schneidervin and Hubert 1986, Secor et al. 1991). A pair of long, thin forceps is helpful in locating and removing otoliths. Although the extraction technique is readily learned, experience and repetition are essential to locating otoliths quickly and consistently.

Otoliths should be stored in vials containing water, ethanol or a mixture of water and glycerin (plus an antifungal agent). Do not store otoliths in formalin since decalcification will occur (Devries and Frie 1996).

The crack and burn technique described by Beamish and Chilton (1982) is useful to determine ages. Otoliths can also be sectioned with a high-speed saw. Otolith preparation and examination is rapid and efficient once the methodology is mastered.

Spines and Fin Rays

Spines and fin rays also provide growth as well as age information. Removal of spines and fins for aging does not require sacrificing the fish. Marginal, second, and third rays or spines from pectoral, anal, and pelvic fins are commonly used for aging (Mackay 1990) and are particularly useful for spiny-rayed fishes and CCF, which do not have scales. Spines and fin rays should be removed from the point of insertion, allowed to dry, and placed in individual envelopes. Removal can easily be accomplished using side-cutters. For percids, remove the first three dorsal and, for CCF, the left pectoral spine at the point of insertion.

Spines and fin rays must be mounted in a hardening agent like epoxy, then sectioned into thin wafers to identify annuli. A Dremel-operated sectioning tool has been developed for the WGFD and is available to all biologists. Experience is essential for efficient and effective spine sectioning. Examination is accomplished under magnification. Annuli identification can be enhanced by applying drops of a solvent like toluene or mineral oil to the sectioned wafers to highlight density contrasts. Lighting adjustments also enhance contrast. When properly prepared and mounted, age determination and annuli measurements are readily accomplished and accurate. Mounting and sectioning, however, can be tedious and time consuming.

Age and Growth

Fish growth is not fixed. Unlike most other vertebrates, growth occurs throughout the life of a fish, although a fish's growth rate decreases with increasing age. Growth rate varies seasonally and annually, depending on many variables including metabolic rate, forage availability, spawning activity, and environmental influences.

Back-calculation is useful to determine a fish's growth over time. Back-calculation is a mathematical comparison of the length of the fish at each year of age to the distance from the focus of the aging structure to each successive annulus.

Fish begin generating annuli at birth in both otoliths and spines. Since fish do not develop scales immediately after hatching, there is a delay in laying down annuli. The Direct Proportion Method can generally be applied when using otoliths or spines for all species. For non-salmonids the Fraser-Lee Method should be used with scales for back-calculation. The standard intercepts for spiny-rayed fishes are documented in Carlander (1982). Scales can not be used to back-calculate ages for salmonids since no published intercepts are available.

Useful descriptions of both the Direct Proportion and Fraser-Lee methods can be found in Devries and Frie (1996).

For both age determination and growth calculations, multiple annuli "readers" should be used to ensure consistency in aging between biologists and for validation.

Archiving Aging Structures

All aging structures should be archived for future use. As methods for aging fish and calculating growth improve or change, it may be advisable to reevaluate historical age and growth data. Each archived sample should be completely labeled to allow for accurate identification on species, size, origin and time of collection.

Statistical Analysis

One definition of "science" is: The knowledge of truths ascertained by observation, experimentation, and induction. Statistics is the field of science that provides a means of measuring the amount of subjectivity that goes into scientific conclusions and thus separates "science" from "opinion" (Conover 1980). Since fisheries managers often make management decisions based on observations from population sampling, statistics is an important tool for managers to determine whether an observation was "real" or simply a factor of "chance".

This section discusses useful statistical procedures with examples of some of the statistical techniques commonly used by WGFD fisheries managers. Assumptions and applications of some of the different statistical tests will be discussed along with some of the statistical software tools available to biologists. This summary is meant to be a basic guide to using statistical techniques in WGFD fisheries management but does not provide a comprehensive synopsis of the mechanics of individual statistical tests. Rather, a list of literature at the end of this summary can be referred to when more detailed information is needed.

Statistical Methods in Fisheries Management – The Experimental Approach

In the text "Inland Fisheries Management in North America", Krueger and Decker (1999) defined fisheries management as: The use of all types of information (ecological, economic, political, and sociocultural) in decision making that results in actions (e.g., regulations) to achieve goals established for fish resources.

Modern college curricula in fisheries management emphasize the use of goals with measurable objectives to assess the effects of management actions. Scientific research provides sound, defensible data that can be used to measure management objectives. Integral to scientific research is the application of appropriate statistical tools and sampling designs.

Fisheries managers should take an experimental approach to evaluating fisheries. Statistical methods should be employed to make conclusions about trends or relationships in aquatic resources. Management decisions should be considered as experiments, with objectives that can be evaluated through scientific research.

Descriptive Statistics

The field of statistics can be divided into two general areas that apply to fisheries management: descriptive statistics and inferential statistics. Descriptive statistics are simple measures that describe location and dispersion of a sample distribution. Statistics that describe location include measures of central tendency such as mean (the sample average), median (the midpoint of a distribution) and mode (the value that occurs the most frequently in the sample). Along with location, investigators would want some idea of the precision of the sample, which could be described using statistics such as range (the difference between the largest and smallest observations), sample variance (s2) and sample standard deviation (s). Another statistic of dispersion is the standard error (SE) of the mean. While these statistics provide technical descriptions of sample precision, they are not always very intuitive. A simple way to characterize sample precision is with the coefficient of variation (CV), which is the proportion of a sample's standard deviation to it's mean. A useful way to express a samples location and precision is with the confidence interval (CI). Very seldom are sample means true estimates of population means. A CI consists of a range of values that bracket the true population mean with some level of confidence (e.g., 95%). A 95% CI means that if a population was resampled 100 times and the CI was recalculated each time, 95 of those CI's would contain the true mean.

Whenever a mean is used to describe a sample, it should be accompanied by some measure of the spread (precision) of the data.

Example 1. Describe the sample CPUE (fish/haul) of RBT captured in the large purse seine during annual sampling of Alcova Reservoir in August 2001 (formulas for these calculations appear in Appendix A).

The number of RBT captured in each of 10 purse seine hauls was:
22, 29, 41, 12, 45, 37, 14, 26, 18, 18

From these data the following statistics are calculated:

Range	= 31 or 14-45
Mean	= 26.2 RBT/haul
n	= 10 hauls
s	= 11.5
SE	= 3.6
95% CI	= (18.1, 34.3)
CV	= 44

Thus, the investigator concludes that 10 purse seine hauls on Alcova produced from 14-45 RBT per haul, with a mean of 26.2. The coefficient of variation indicates that the standard deviation is 44% of the mean, and the confidence interval suggests that the true population mean lies somewhere between 18.1 and 34.3.

In this example several statistics were calculated and reported for illustration. To keep reports concise investigators may want to report only one measure of dispersion. The CI and CV provide intuitive information on the spread of the data. However, **standard deviation and sample size should always be reported** so that they are available to other investigators for use in inferential statistical tests.

Inferential Statistics

A common form of inferential statistics is the hypothesis test. Fishery managers may want to know if an observed change in fish data (e.g., the mean length of age-1 WAE in Seminoe Reservoir) is due to an actual change in the population or is simply an artifact of sampling variation. The manager would formulate a hypothesis, the null hypothesis (Ho), that states that the two populations are similar (e.g., Ho: mean length at time t = mean length at time t+1). The alternative to this would be that the populations are not equal, and this is termed the alternative hypothesis (HA). Once the hypotheses are formulated, the manager would select an appropriate test to calculate a test statistic. Using the test statistic and a probability table, the investigator can obtain the probability (P-value) that the null hypothesis is correct. Thus, a very small P-value suggests that there is very low probability that the two populations are similar. At some point, the manager must determine how low the P-value should be before the null hypothesis is rejected. This level is called the level of significance. A commonly used level of significance is 0.05, but values typically range from 0.01-0.1. A level of significance of 0.05 means that there is only a 5% chance of the null hypothesis being correct. Thus, the manager would choose to reject the null hypothesis with a 1 in 20 chance of the decision being wrong.

Parametric vs. Nonparametric Statistics

Parametric statistics refers to the branch of statistical methods that are based on normal distributions of data. This branch of statistics includes commonly used techniques like t-tests, F-tests, and regression analysis. When applying parametric methods, investigators need to be aware of the underlying distribution of their data. Many statistical software programs provide tools to test for normality (e.g., Shapiro-Wilks W test for normality) and to visually assess departures from normality through normal probability plots. Oftentimes nonnormal data can be transformed to provide a distribution that is more normal and thus, favorable for parametric statistics.

Occasionally investigators may encounter a data set that is nonnormal and cannot be transformed to approximate normality. Nonparametric statistics can be applied to such data. Nonparametric statistics refers to the branch of statistical methods that do not depend upon a specific distribution of data. Most common parametric statistics have nonparametric counterparts (Table 1).

Since nonparametric statistics require less stringent assumptions than parametric statistics, investigators may be inclined to apply nonparametric methods to all data sets regardless of their distribution. In fact, nonparametric statistics can be applied to most data sets. However, when the assumptions of normality are met, parametric tests are more efficient (i.e., they have lower statistical error) than nonparametric tests. Thus, investigators need to be aware of the distributions of their data and apply the test that is most appropriate and efficient.

Table 1. Typical parametric tests and their counterparts (adapted from Brown and Austen 1996).

Parametric test	Corresponding nonparametric test
Independent t-test	Mann-Whitney test
Paired t-test	Wilcoxin signed rank test
ANOVA	Kruskal-Wallis test

Parametric Hypothesis Tests

Hypothesis testing is performed when scientists want to determine whether two or more samples are significantly different. The general null hypothesis is that the samples are not significantly different, and the alternative hypothesis is that a significant difference does exist. Many types of hypothesis tests exist. This section will outline some of the tests commonly used in fisheries management, with specific examples from WGFD data. Appendix 2.2 in Brown and Austen (1996) and Kanji (1993) provide useful lists of many statistical tests and their applications.

Independent t-test

An independent t-test is used to determine if two unrelated samples are significantly different. Using the standardized sampling methods outlined in this manual, an independent t-test can be used to compare data collected at different reservoirs or at different times within a reservoir. For instance, managers may want to know if fish population parameters such as growth, relative weight, size structure, etc., are similar between two reservoirs or between two time periods within a reservoir.

Example 2: Suppose managers wanted to know how WAE growth differed between Glendo and Boysen Reservoirs. They could test the mean lengths at age 4 from 2001 sampling data to determine whether one population grew faster than the other. The managers assume that the data for this test are normally distributed.

The hypotheses would be:

H_o: (Mean length at age 4)$_{Glendo}$ – (Mean length at age 4)$_{Boysen}$ = 0
H_a: (Mean length at age 4)$_{Glendo}$ – (Mean length at age 4)$_{Boysen}$ $\neq$ 0

The data for the two reservoirs are:

	Glendo	Boysen
n	35	34
Mean Length (in)	18.9	15.0
s	1.1	1.6

Substituting population values into the equation for an independent t-test in Appendix B:

$$t = \frac{(18.9 - 15.0)\sqrt{\frac{35 \bullet 34}{35 + 34}}}{\sqrt{\frac{(35-1)1.1^2 + (34-1)1.6^2}{35 + 34 - 2}}}$$

$$t = \frac{16.2}{1.37} = 11.8$$

Thus, the investigator obtains a t-statistic of 11.8 with 34 + 35 – 2 = 67 degrees of freedom. The investigator would use a t-table (found in most statistical texts) to obtain a P-value = 0.000. From this it is concluded that there is 0.000 chance that the null hypothesis is true and so the null hypothesis is rejected. It appears that WAE length at age 4 is significantly different between Glendo and Boysen Reservoirs, and thus, WAE growth is faster at Glendo.

Paired t-test

The paired t-test is used to determine if statistical differences exist between samples of paired data. Paired data occur when the two samples are dependent (i.e., observation 2 depends on observation 1, or when the treatment affects two groups sharing the same experience). An example of paired comparisons given by Brown and Austen (1996) is of weight change of LMB over time. Five LMB were weighed, held for a time, and then weighed again. The investigator wanted to determine whether the mean weight of LMB changed from time 1 to time 2. Since the same fish were weighed, the weight at time 2 was dependent on weight at time 1. This type of scenario is useful when fish are held in laboratory conditions or when tagged fish can be resampled, but it doesn't occur frequently during fisheries management sampling. In Wyoming fisheries management, a paired t-test may be appropriate to test for annual differences in relative abundance (e.g., gillnet CPUE, purse seine catch/haul, sonar fish/acre, etc.) using the same standard sampling locations.

The calculations for the paired t-test differs from the independent t-test calculations because the paired t-test does not directly test the mean values and their variances for differences. Rather, the paired t-test examines the differences between the paired observations to determine whether the mean difference is different from some hypothesized value, typically zero if no difference occurs.

Example 3: Boysen Reservoir is sampled annually using 6 FG and 6 EG set in standardized locations. In recent years, there has been an increase in RBT CPUE in FG, and managers want to know if this increase was significant. A paired t-test is employed to determine if RBT CPUE in FG is significantly greater in 2001 than in 2000. It is assumed that the data for this test are normally distributed. Only 5 nets are shown in the example because low water forced the move of site number 4 between years.

The hypotheses would be:

H_o: $CPUE_{2001} - CPUE_{2000} = 0$
H_a: $CPUE_{2001} - CPUE_{2000} > 0$

Net	2000 CPUE	2001 CPUE	d	d^2
1	0.2	0.5	0.3	0.1
2	0.2	0.9	0.7	0.5
3	0.1	1.0	0.9	0.8
5	1.0	1.0	0.0	0.0
6	0.4	0.8	0.4	0.2
Sum			2.3	1.6

Mean d = 2.3
$\sum d^2$ = 1.6
$(\sum d)^2$ = 5.3

For a paired t-test, *s* needs to be calculated first (see Appendix B for formulae):

$$s = \sqrt{\frac{5(1.6) - 5.3}{5(5-1)}} = \sqrt{\frac{2.7}{20}} = 0.4$$

$$t = \frac{0.5 - 0}{0.4/\sqrt{5}} = 2.8$$

df = n - 1 = 4

P = 0.024

The P-value indicates that there is a 2.4% chance that the H_o is correct, so the H_o should be rejected. It appears that the increase in RBT CPUE from 2000 to 2001 was significant.

Multivariate tests

Often investigators will want to test for differences among more than two populations. Multivariate tests address this task through their ability to test several simultaneous measures.

The analysis of variance (ANOVA) is one of the most commonly used parametric multivariate tests. The phrase ANOVA refers to the idea of analyzing variability in the data to determine how much can be attributed to differences in population means and how much is due to variability in the individual population. As with other tests, investigators need to be aware of the assumptions of ANOVA (from Devore and Peck 1997):

Each population's or treatment response's distribution is normal
The populations have similar variances
The observations within the sample from each population were collected independently
The samples from each population are independent of each other

The test statistic calculated for the ANOVA is the F-statistic. When two samples are being compared, the F-statistic produces identical results to a t-statistic. Computations for the F-test are more complex than for the t-test, and computer statistical programs are typically employed to facilitate computing.

While the ANOVA is useful for detecting inequalities among the population means, a multiple comparisons test is required to determine which means are significantly different. There are many methods available to perform multiple comparisons (e.g., Tukey-Kramer, Student's t-test, Dunnett's test, etc.) under certain conditions. Investigators should refer to the literature section for sources of more complete descriptions of multiple comparisons.

Example 4: The ZPR index is used to assess the amount of large zooplankton available to planktivores such as RBT. The ZPR was measured monthly from August-October at Jackson Lake in 1998. An ANOVA can be applied to those measurements to test whether there was a significant monthly difference in the amount of large zooplankton in Jackson Lake. The first step is to state the hypotheses:

H_o: $ZPR_{August} = ZPR_{September} = ZPR_{October}$
H_a: *At least one* of the mean ZPRs is significantly different from the others

Assuming the data are normally distributed, the test can be performed. The results from the ANOVA are in Table 2. The calculated test statistic (F) is 5.847 with a corresponding P-value of 0.0083. Thus, there is little probability that all of the months have the same mean ZPR, and the H_o is rejected.

Table 2. Results of ANOVA to test for differences in mean monthly $ZPR_{750:500}$ at Jackson Lake, August-October, 1998.

Source of variation	DF	SS	MS	F	P
Month	2	0.24669	0.12335	5.847	0.0083
Error	25	0.52733	0.02109		
Total	27	0.77402	0.02867		

Now that the H_o has been rejected, there is information that the ZPR changed by month. But it is unknown which months are different. A multiple comparisons test can be used to answer this question. One type of multiple comparisons test, a Tukey-Kramer test, examines the differences of the means of each variate and tests to determine whether that difference is significantly different from zero. If it is, then the variates are considered significantly different. Using JMP IN it is determined that the three months have the following ZPR hierarchy:
August > September = October

Thus, it is concluded that August's ZPR is significantly higher than September and October, which are not significantly different from each other.

Nonparametric Hypothesis Tests

Chi-square test

The chi-square (χ^2) test is also known as a "goodness of fit" test to compare observed frequencies in a sample to some hypothetical frequency. A commonly used example of the χ^2 test is to determine whether two types of stocked fish survived at the same rate by comparing the ratio of each type of fish in a sample to the ratio of each type of fish originally stocked.

Example 5: Casper regional fisheries managers wanted to determine whether 7" RBT survived as well as 9" RBT in Pathfinder Reservoir. They stocked marked 7" and 9" RBT at a ratio of 0.52:0.48. They subsequently captured 588 marked RBT, of which 265 were from the 7" group and 323 were from the 9" group. A χ^2 statistic can be calculated, using the formula in Appendix B, to determine whether the ratio of 7:9 inch fish returned matches the ratio of 7:9 inch fish stocked.

H_o: The ratio of 7:9 inch fish in the sample = 0.52:0.48
H_a: The ratio of 7:9 inch fish in the sample $\neq$ 0.52:0.48

$$\chi^2 = \frac{[323-(0.48)(588)]^2}{0.48(588)} + \frac{[265-(0.52)(588)]^2}{0.52(588)} = \frac{1681}{282} + \frac{1681}{306} = 11.5$$

From a χ^2 distribution table with 1 df, the P-value for this test is <0.001. The H_o that the two sizes of fish have the hypothesized ratio in the sample is rejected.

Other Nonparametric Tests

Many of the common parametric hypothesis tests (e.g., independent t-test, paired t-test, ANOVA) have nonparametric counterparts (e.g., Mann-Whitney test, Wilcoxin signed rank test, Kruskal-Wallis test). The primary difference between parametric and nonparametric tests is that nonparametric tests do not require a specific underlying probability distribution. Rather, a nonparametric test examines the distributions of data variates for differences, under the assumption that the distributions are similarly shaped. As with parametric statistical tests, each nonparametric test has unique assumptions. Some general assumptions that apply to most tests include:

- Samples are randomly taken from their respective populations.
- There is independence between samples.
- The measurement scale is at least ordinal.

This summary will not discuss each of the nonparametric tests available. Biologists should be aware that these alternatives exist, but should attempt to use parametric methods whenever possible because parametric methods are more efficient and provide additional information, such as variance, that nonparametric methods do not provide.

Types of Error and Power of a Test

Investigators should note that statistical tests are not 100% conclusive. Two types of errors may occur during hypothesis testing. Type I error (denoted α) is committed by rejecting the null hypothesis when the null hypothesis is true. The probability of Type I error is the same as the significance level of the test, which is why the significance level of a test is also commonly denoted as α. Type II error (denoted β) is the probability of accepting the null hypothesis when the null hypothesis is actually false. Type I and Type II errors are inversely related. This poses a problem for investigators who want to minimize both types of error, because when one is reduced the other is increased. The most common compromise is to set α at some pre-determined level and select a test that maximizes statistical power (Brown and Austen 1996). Statistical power (1- β) is the likelihood of rejecting a null hypothesis when the alternative hypothesis is correct. Statistical power is important because if power is low there is little chance of finding significant differences, even when real differences exist. Power can be increased while maintaining low α by increasing sample size or by improving the precision of the dataset. Peterman (1990) and Steidl et al. (1997) provide useful syntheses of statistical power and various methods for conducting power analysis, as well as examples of applying power analysis to fisheries and wildlife management.

Dealing with Nonnormality

The assumption of normality is important for many of the statistical tests presented in this summary. Unfortunately, that assumption is not always met. Since parametric tests provide more information than nonparametric tests, measures can be taken to transform nonnormal data to provide a distribution more conducive to parametric tests. Skewness to the right can often be lessened by a square-root, logarithmic (base 10 or base e), or other transformation to a power less than one, while skewness to the left is lessened by a square, cube, or other transformation to a power greater than one.

Outliers can cause distributions to appear skewed due to unusually large or small values. Data sets should be examined to determine whether outliers are due to sampling or entry error, or whether they represent real data values. If outliers are due to error, the error should either be corrected or the outlier excluded from further analysis. If the outliers are due to real values in the data set, the values should be kept in the analysis.

If transformation or outlier analysis do not provide a distribution conducive to parametric testing, nonparametric tests should be considered.

Statistical Software

Microsoft Excel offers capabilities to perform simple statistical analyses. However, users should be aware that many of the more advanced statistical calculators in Excel are incorrectly named and produce misleading or erroneous results (http://www.rdg.ac.uk/ssc/dfid/booklets/topxfs.html ; http://www.cs.uiowa.edu/~jcryer/JSMTalk2001.pdf). Excel seems to work well to produce basic descriptive statistics, but inferential statistics should be calculated either by hand or by using a proprietary statistics package. Several packages exist as add-ins to Excel, that actually perform the analyses directly in the spreadsheet (http://www.analyse-it.com/ ; http://www.xlstat.com/indexus.html). Though the authors of this section have little experience with these packages, they appear to provide correct results in a reasonably priced package.

Investigators interested in regularly performing statistical analyses should consider a proprietary statistics software package. The tools incorporated in such a package are more than adequate for most fisheries management analyses and the software is becoming increasingly user-friendly with the development of menu-driven programs. There are several brands of software available, and the authors are aware of at least four programs currently being used by WGFD Fish Division biologists: JMP (http://www.jmpdiscovery.com/), Minitab (http://www.minitab.com/), Statistix (http://www.statistix.com/home.html) and SYSTAT (http://www.systat.com/).

The internet provides many useful websites concerning statistical methods. Some of these websites provide easy-to-understand advice, while others provide reliable calculators to perform simple analyses (e.g., power analysis). Here is a sample of some websites the authors have found useful:

http://home.stat.ucla.edu/
http://ebook.stat.ucla.edu/calculators/
http://home.clara.net/sisa/
http://www.statsoft.com/textbook/glosfra.html

Special Considerations

Proper statistical analysis is an essential component of science-based fisheries management. Suitable statistical analysis leads to appropriate and defendable management actions.

Biologists need to be aware of the assumptions (ex. normality, independence, etc.) that must be met for each particular statistical test before performing any statistical analysis.

Whenever a mean is reported it should be accompanied by sample size and standard deviation. This allows other biologists to use the data in inferential statistical tests.

P-value should be reported for all tests of hypotheses.

Selected Statistical Literature

Citations in bold print denote texts that provide comprehensive treatments of many of the subjects discussed in this summary

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Zar, J.H. 1998. Biostatistical analysis, 3rd edition. Prentice-Hall, Englewood Cliffs, New Jersey.

Formulas for Simple Descriptive Statistical Calculations

<u>Sample Mean</u>

$$\bar{x} = \frac{\sum x_i}{n}$$

<u>Sample Variance</u>

$$s^2 = \frac{\sum x^2{}_i - \frac{(\sum x_i)^2}{n}}{n-1}$$

<u>Sample Standard Deviation</u>

$$s = \sqrt{s^2}$$

<u>Standard Error of the Mean</u>

$$SE = \frac{s}{\sqrt{n}}$$

<u>Confidence Interval</u>

$$CI = \bar{x} \pm t_{n-1}(SE)$$

<u>Coefficient of Variation</u>

$$CV = \frac{s}{\bar{x}}$$

Formulas for Simple Inferential Statistical Tests

<u>Independent t-test Statistic</u>

$$t = \frac{(\bar{x}_1 - \bar{x}_2)\sqrt{\dfrac{n_1 n_2}{n_1 + n_2}}}{\sqrt{\dfrac{(n_1 - 1)s_1^{\,2} + (n_2 - 1)s_2^{\,2}}{n_1 + n_2 - 2}}}$$

df = n1 + n2 – 2

<u>Paired t-test Statistic</u>

$$s_d = \sqrt{\frac{n(\sum d^2) - (\sum d)^2}{n(n-1)}}$$

where d is the difference between paired observations.

$$t = \frac{\bar{d} - \mu_d}{s_d / \sqrt{n}}$$

df = n – 1

<u>Chi-square Test Statistic</u>

$$\chi^2 = \sum \frac{(O - E)^2}{E}$$

Where O is the observed frequency in a given class and E is the expected frequency in a given class.

df = n – 1 classes

CHAPTER 4 -- DATA PROCESSING AND REPORTING

Data Entry

Standing water fishery field data must be entered into each crew's copy of the Lakestn database, located in the Fishdata folder. Each sampling event should include water name, collectors' names, date sampled, and any relevant comments. Each net should be entered as a separate entry so that data can be analyzed by net and location. Database fields for each net require units of effort (hours set, nights set, number of hauls). Optional information includes a brief site location description and minimum and maximum depth. GPS coordinates can be entered using the button labeled Gear Location UTM.

For each net, all measured fish of each species should be entered individually in inches. Optional information for each fish includes weight, mark, tag number and sex. For weighed fish, relative weight will be automatically calculated with fish outside accepted ranges denoted in blue type as a data entry error check. The total number of unmeasured fish of each species should be entered using the Not Measured button.

Following data entry, individual fish information can be reviewed and summaries of data can be generated, including averages and CPUE. Various reporting options are available, including summaries by gear location, measured fish summaries, and length frequency spreadsheets. These summaries can be used when preparing tables for annual progress reports, administrative reports, or other forms of information analyses and distribution.

Reporting

Lakestn database-generated tables will be developed for export to Microsoft Word for inclusion in reports. Tables will be standardized both in content and format. Using standardized tables and figures will be important in facilitating comparisons of data collected between sampling events and between waters.

All reports will be formatted as outlined in the Formal Report Procedures section of the Fish Division Procedures Manual. Reports containing data collected using standardized methodology will follow the guidelines for tables and figures presented in this section.

Tables

Table headers will precede the table. Two hard returns should separate the table from the body of the report on both the top and bottom, with one hard return between the table and the header text. All type should be Times New Roman, 11 pt.

Netting data will be reported as presented in Tables 1 and 2. Note that CPUE, mean length, mean weight, and RSD information is presented in separate tables for each gear type. However, body condition information (Wr) is combined for all gill nets and presented in another table. Zooplankton data will be reported as presented in Table 3.

Table 1. Number, CPUE (stdev), mean length (n; stdev) with ranges, and mean weight (n; stdev) with ranges of fish captured in FG, Boysen Reservoir, September 10-12, 2002. (6 nets, 91.5 hours).

Species	Number	CPUE	Mean Length	Range	Mean Weight	Range
BLC	2	0.02 (0.03)	11.6 (2; 0.2)		1.0 (2; 0)	
BNT	1	0.01	20.3		3.3	
CCF	3	0.03 (0.09)	15.8 (3; 3.6)	12.7-19.8	1.3 (3; 0.6)	0.8-2.0
CRP	8	0.09 (0.14)				
RBT	51	0.56 (0.25)	18.0 (51; 1.5)	14.8-21.2	2.3 (51; 0.6)	1.3-4.0
RCS	2	0.02 (0.06)				
SAR	2	0.02 (0.06)	15.5 (2; 0.5)	15.2-15.9	1.2 (2; 0.3)	1.0-1.4
WAE	63	0.69 (0.25)	16.2 (63; 1.3)	11.1-20.0	1.6 (63; 0.4)	0.5-2.8
TOTAL	129	1.41 (0.33)				

Relative Stock Density for RBT and WAE.

Species	n ≥ S	RSD-Q	RSD-P	RSD-M	RSD-T
RBT	51	80	14		
WAE	63	87	2		

Table 2. Mean relative weights (n; stdev) with ranges and relative weights by length category (n; stdev) for selected fish species captured in all gill nets (FG and EG), Boysen Reservoir, September 10-12, 2002.

Species	Mean Wr	Range	S-Q	Q-P	P-M	M-T
CCF	91.3 (3; 5.0)	86.0-96.0				
RBT	88.0 (51; 10.2)	62.6-109.7	86.6 (7; 10.9)	89.2 (53; 9.5)	82.4 (9; 12.8)	
SAR	81.8 (2; 6.4)	71.4-97.3		78.8 (9; 4.7)	82.9 (24; 6.7)	
WAE	95.6 (63; 7.7)	66.8-132.1	96.5 (31; 6.9)	95.6 (148; 7.8)	84.8 (2; 6.7)	88.6 (2; 5.8)

Table 3. Mean volume (ml) and ZPR ratios for samples collected with vertical tows in Pathfinder Reservoir.

Net Mesh	Year	May	June	July	August	September	October
500 μ	1994	-	33	14	19	11	15
	1995	27	46	17	16	-	-
	1997	-	-	32	10	10	5
	1998	-	-	49	14	23	-
	1999	38	43	33	-	8	-
750 μ	1994	-	16	11	14	9	9
	1995	18	26	12	12	12	-
	1997	-	-	13	4	6	2
	1998	-	-	19	9	16	-
	1999	19	35	19	-	6	-
750:500	1994	-	0.48	0.79	0.74	0.82	0.60
	1995	0.67	0.57	0.71	0.75	-	-
	1997	-	-	0.41	0.40	0.60	0.40
	1998	-	-	0.39	0.64	0.70	-
	1999	0.50	0.81	0.58	-	0.75	-

Figures

Figure captions should be located below the figure it describes, but in all other ways the header formatting is the same as for tables. Type should be Times New Roman in bold style, sized as follows:

Chart title – 12 pt
Axis titles – 11 pt
Axis labels – 8 pt
Legend – 8 pt

Length frequency data will be reported as shown in Figure 1. Oxygen and temperature data should be reported as shown in Figure 2.

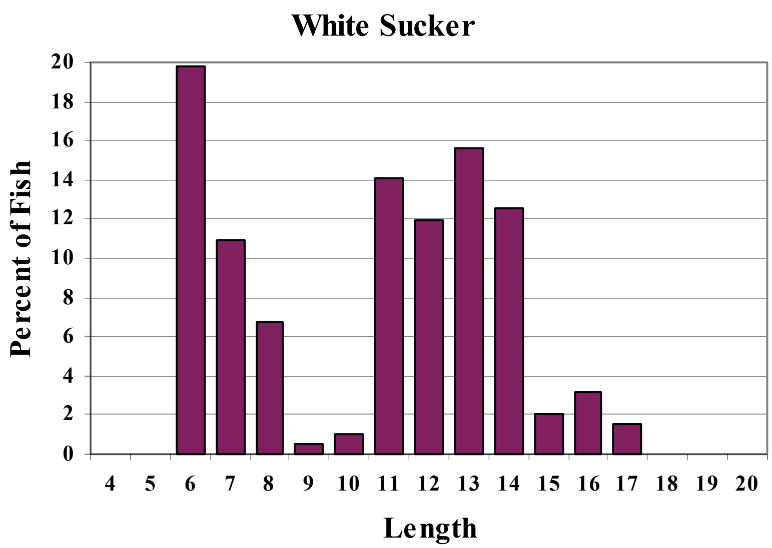

Figure 1. Length frequency of WHS captured in EG, Jim Bridger Pond, May 1997 (n=100).

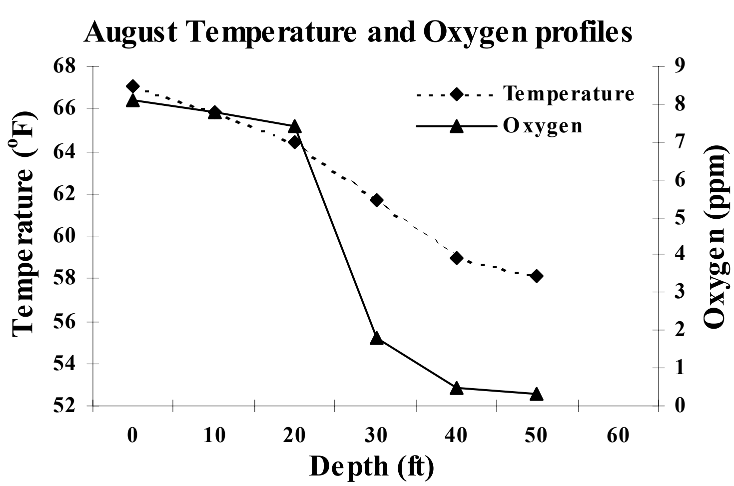

Figure 2. Temperature and oxygen profiles, Viva Naughton Reservoir, August 2000.

CHAPTER 6 -- ANGLER SURVEY

The ultimate goal of nearly all fisheries management and research on large standing waters in Wyoming is to provide recreational opportunities for anglers. While native fish and other resource issues also deserve the attention and concern of managers, they are generally secondary to sportfish management in these large, often artificial waters. It is logical, therefore, that any assessment of fisheries management programs should incorporate some measure of angler success or satisfaction. Intensive programmed creel surveys are periodically conducted on many of the large standing waters within Wyoming. These surveys attempt to gather data to allow for calculation of as many aspects of fishing use and success as possible and yield monthly estimates of pressure, a multitude of catch statistics, angler residency information, etc. They are most often conducted for 3-6 months during the open water period. Angler counts from aircraft and on-the-ground interviews are typically performed during eight days or more each month. The cost and manpower associated with these surveys has caused their use to be questioned in recent years. While an intensive programmed creel survey may still be appropriate for certain situations, prudent use of available funds has required that biologists develop new and innovative methods to acquire sufficient data to make management decisions while keeping expenditures of time and money to a minimum. Key to such an approach is the development of specific, measurable management goals and objectives by which the fishery is to be managed. By developing management goals or criteria beforehand, angler surveys can often be designed to answer only the specific questions of interest or provide the needed data to evaluate the goals or criteria. Such surveys can potentially be far less costly and time consuming than the traditional programmed creel survey.

The science of surveying anglers and their catch is one of the major tools utilized by fisheries managers throughout North America. The type, complexity, and extent of surveys vary widely. Anyone who considers conducting an angler survey is encouraged to consult Pollock et.al. (1994). This publication gives a good overview of the majority of survey types in use today and provides guidance for designing and analyzing surveys as well as minimizing bias and imprecision. It covers both on-site surveys (access, roving, aerial) and off-site surveys (mail, telephone, angler logs, catch cards) but does not deal directly with what have become known in Wyoming as index creel surveys and spot creel surveys. Much of the terminology and naming convention found within Pollock et.al. (1994) will be used within this section to promote uniformity both within Wyoming and with other agencies. The following terms were taken directly from that publication or are those that have evolved and become generally accepted within the WGFD.

Angler survey: General term for any survey of anglers by an on-site or off-site method.

Creel Census: On–site angler survey that samples every sampling unit in the population. The phrase "creel census" is often used erroneously when referring to a "programmed creel survey." WGFD has not conducted a creel census on any large reservoir due to financial and logistical constraints.

Creel survey: On-site angler survey during which anglers' harvests are examined by the creel clerk.

Programmed creel survey: A creel survey that follows accepted statistical sampling theory in an attempt to achieve estimators of interest that are unbiased and precise.

Short duration programmed creel survey : A creel survey that is conducted with the intensity of a programmed creel survey, but during an abbreviated time period (as short as one month). Usually performed during the period of heaviest fishing pressure as an indication or measure of certain parameters of the fishery.

Index count: A survey that incorporates periodic counts of something that is believed to be correlated with angling pressure. Some examples of index counts are numbers of boats in a particular section of a large reservoir, vehicles in a specific parking area, vehicles with empty boat trailers, boat slips in a marina, or anglers on a popular length of shoreline.

Spot creel survey: A creel survey that does not incorporate complete angler counts, but rather utilizes angler contacts and possibly index counts to gather information related to angler success, harvest rate, and pressure.

Sampling frame: Complete set or list of all sampling units. The frame for on-site surveys is usually a list of fishing areas to be surveyed and fishing days in the fishing season. The frame for off-site surveys might be a list of anglers to be contacted via telephone or mailing.

Sampling unit: Basic unit of sampling (e.g., an angler or a particular combination of space and time).

Instantaneous count: Count of anglers or boats made quickly from an airplane, a vantage point (bridge, hilltop, etc.), a fast-moving boat, or an automobile. In practice, these counts are not truly instantaneous.

Progressive count: Count of anglers or boats made over time as a survey agent moves through a fishery area. Within each small subarea, the count may be instantaneous.

On-Site Angler Surveys

On-site surveys are those that involve contacting or counting the anglers directly. For these surveys, the sampling unit is some time interval (day, half day) or a location (access point, boat ramp, etc.). By having a trained creel clerk contact anglers and examine catch, on-site surveys have the advantage of reducing bias associated with species misidentification, fish measurement error, and what Pollock et.al. (1994) refer to as prestige bias (anglers may exaggerate their catch rate and size of the fish they caught in self-reported surveys). Prestige bias may still be a problem in on-site surveys, particularly catch and release fisheries, if anglers exaggerate the number and size of fish they released. Recall bias is reduced for on-site surveys, but may still effect the outcome of some estimates. One of their major disadvantages is the high cost associated with conducting on-site surveys.

Programmed Creel Survey

A programmed creel survey is an on-site survey that includes instantaneous angler counts for the estimation of fishing pressure and access point and/or roving survey of anglers to obtain catch information and angler demographics. A programmed creel survey is typically conducted for a 3 to 6 month period during the peak fishing season, but may last up to a ~~or~~ year. In an attempt to approximate a true instantaneous count of anglers, aircraft is often utilized when making angler counts for large lakes and reservoirs. Days to conduct sampling are usually stratified by type – weekdays and weekend days. Each day is then often divided into two or three secondary sampling units to facilitate calculation of an average instantaneous count for each day. The Fish

Population Supervisor, or other statistician familiar with survey design, should be consulted to assist in the design of a programmed creel survey.

Programmed creel surveys and other on-site surveys disproportionately sample avid anglers because these people are encountered more frequently. This disproportionate sampling is necessary if the survey objectives are to estimate angling pressure, total catch, or catch rates. If the objectives of the survey include characterizing the population of anglers in terms of demographics, economics, or attitudes, disproportionate sampling can result in "avidity bias". This bias can be minimized if the survey is designed so that any questions regarding demographics, attitudes, or opinions are only asked of each angler once during the course of the survey. If not, then care should be taken as to how the information is reported. For example, if the county or state of residence were asked during each interview and 50% of the respondents indicated they were residents of Wyoming, it would be incorrect to report that 50% of the anglers were from Wyoming. More correctly, it could be stated that 50% of the angler days were expended by residents of Wyoming.

As performed in Wyoming, programmed creel surveys have been roving surveys, access point surveys (boat ramps, parking lots, etc.), or a combination of the two. Access point surveys have the advantage of gathering more information from completed trips. However, when use is not restricted to defined access points a roving type survey is necessary to obtain a representative sample of all anglers. When doing roving surveys it is important that potential biases are understood. Roving clerks may interview disproportionately more anglers who have been fishing longer than average. If mean trip length is estimated from roving clerk interviews, it could be biased high. Catch rate may also be biased from roving creel surveys. If successful anglers tend to fish longer (because they are catching fish and having fun!) and unsuccessful anglers quit early (because they aren't catching fish), catch rate will be biased high (if probability of being interviewed increases with trip length). On the other hand, if successful anglers have shorter than average trips because they leave after catching their limit, catch rate will be biased low.

Considering the cost, the need for aerial surveys to obtain estimates of fishing pressure should be evaluated carefully. Aerial counts may indeed be necessary for estimating total pressure and catch on large reservoirs, but unless that information is absolutely necessary to make a management decision, aerial counts have become too costly to conduct simply for the sake of having the information. An analogy can be made with estimates of fish population sizes within large lakes and reservoirs. These estimates may be useful for the management of large standing waters, but because of the impracticality of obtaining them we have developed strategies for managing fisheries and making decisions based on netting data that do not yield estimates of population size. Similarly, data other than actual estimates of fishing pressure and total catch are often adequate to describe the characteristics of a fishery.

Glendo Reservoir Programmed Creel Survey

From April through September 2000 a programmed creel survey was conducted on Glendo Reservoir. The purpose of this creel survey was to determine angler use, harvest and attitudes (Mavrakis 2001). The survey was funded by the Bureau of Reclamation (BOR) to provide data for the Platte EIS process. The BOR desired information on the total pressure and catch on Glendo Reservoir to demonstrate the value of the fishery. The creel sampling schedule was based on a stratified two-stage sampling regime. The fishing day was the primary sampling unit and defined as sunrise to sunset. The survey period was stratified by month and within month stratified into weekday and weekend days. Counts were scheduled on four weekdays and four weekend days a month. Three counts were done each scheduled day from a fixed wing aircraft. The airplane was used given that the entire reservoir could not be counted from the ground. Angler interviews were conducted on count days and non-count days. Interviews conducted on non-count days were combined with interviews conducted on the nearest count day. The creel clerk collected information on: hours fished, location(s) fished, completed trip, angler type (bank or boat), number of poles, license type (resident of nonresident), residence, tackle type, and species preference. Anglers were also asked about their satisfaction with their angling experience that day and a question about preferred WAE sizes available. Management recommendations resulting from the programmed creel included recommendations for timing and duration of future creel efforts, elimination of CCF stocking, keeping regulations the same as statewide regulations, establishing roadblocks as an annual angler sampling tool, recommendations for additional boat ramps, and continuing work with the BOR for a higher minimum pool at Glendo Reservoir.

Short Duration Programmed Creel Survey

Short duration programmed creel surveys have developed in Wyoming as an alternative to costly programmed creel surveys. They are typically designed similar to a programmed creel survey, but are limited to the period (weeks or months) of heaviest fishing effort. They normally do not include aerial surveys but may include an index count that is correlated with the total count. Management goals based on short duration programmed creel surveys are less expensive to evaluate and can therefore be evaluated more frequently. For example, a management goal might be to maintain a walleye catch rate of 1.0 fish/hour during the month of June.

Grayrocks Reservoir Short Duration Programmed Creel Survey

1994

WAE harvest and catch rates were declining since last measured in 1989. The primary objective of the survey was to update estimates of fishing pressure and harvest compiled during the 1989 programmed creel survey and fine tune the management plan. This survey was also conducted to evaluate the affect of the reduced WAE limit; size restriction on SMB, and elimination of stocking WAE fry for two years (1989 and 1990). Due to budget and personnel limitations a decision was made to conduct the programmed creel survey only during the month of June when the peak of fishing pressure and mean catch rate occurred. Angler interest in WAE minimum lengths and creel limits was extremely high during the early 1990s and information collected was used during numerous public meetings on this subject.

Recommendations included updating the management plan, continued stocking of WAE, maintaining the existing WAE creel limit, and conducting a June creel survey again in 1999 to maintain current information to respond to the high public interest in the Grayrocks fishery (Meyer 1995). Also recommended were periodic (every five years), short-term (one to two months) intensive creel surveys as a useful, cost-effective (compared to fishing season-long surveys) way to measure progress towards objectives such as harvest rates and sizes of fish harvested (Meyer 1995) .

Lake DeSmet Short Duration Programmed Creel Survey

Yearlong creel surveys done on Lake DeSmet in 1991 and 1998 revealed June as the month with the highest angler use. An index creel survey was done during June 2000 and June 2001 to determine comparability and develop trend information to monitor angler use, catch, harvested fish size and changes resulting from changed fishing regulations

Four weekend days and four weekdays were sampled during June of each year following the same methods used during the 1998 creel survey (Bradshaw 2000).

Results indicate these short duration programmed creel surveys will be useful in developing angler use trends as well as determining angler satisfaction parameters. Information obtained during these surveys initially indicates angler satisfaction has increased as a result of fishing regulation changes enacted in January 2000.

Index Counts

The units being counted during index counts are usually selected during a programmed creel, based upon a correlation between the index count and the estimated total fishing pressure. Index count locations should be chosen to include areas where angling is the highest use (Mavrakis and Conder 2001). Investigators are encouraged to select several index parameters to count during a programmed creel survey so they are more likely to identify a relationship between an index count and the total pressure estimate. Assuming that no changes in the fishery or the pattern of angler use has occurred subsequent to determining the correlation, the index count allows for a reliable estimate of total fishing pressure. When both index counts and spot creels are conducted following a programmed creel survey, managers can evaluate management programs based on pressure and catch for years after the initial programmed creel survey estimates become dated.

North Platte River Index Counts

Index counts were obtained on various sections of the North Platte River system during the North Platte Comprehensive Fisheries Study (Mavrakis and Conder 2001). Index counts were counts of vehicles in particular locations at prescribed times. Areas that were believed to have the highest angler use on each water were selected for index counts. Index counts were conducted during the programmed creel survey count days and simple linear regression was used to evaluate the relationship between index counts and angler pressure.

When combined boat and bank angling pressure estimates were regressed against index counts, standing waters used primarily by anglers had strong relationships; Pathfinder ($r^2 = 0.73$) and Seminoe Reservoirs ($r^2 = 0.68$). The comparatively weak relationship at Alcova Reservoir ($r^2 = 0.57$) was attributed to the large number of non-angling vehicles at that water. Biologists planning index counts on reservoirs with high recreational use (other than angling) will be challenged to select an index parameter that performs well. Index counts of vehicles were not reflective of pressure in river sections of the creel survey study area.

Index counts compiled during the programmed creel survey provided an easy and inexpensive method for monitoring post-survey trends in angling pressure.

Road Blocks

If access to a water is limited to a small number of roads, roadblocks can be utilized to sample anglers. This could be considered a type of access point survey in that it involves direct contact with anglers at a discrete point and results in completed-trip interviews. Roadblocks can be used to gather demographic, attitudinal, catch rate, fish size, etc. data and can be employed as often during the fishing season as considered necessary to obtain the desired precision. If angling pressure is the primary variable of interest, car counters (seismic or video) can be employed to estimate numbers of vehicles entering or leaving a water. If employed in conjunction with periodic roadblocks, a correction factor can be developed to eliminate non-anglers from the car counter data and to develop an index count utilizing car counters.

Grayrocks Reservoir One day June Roadblock

The Laramie crew has been using one-day roadblock checks during mid-June to obtain information on angling pressure and harvest. Meyer (2001) recommended: "One-day roadblock checks of Grayrocks Reservoir anglers regularly have been made in past years during June (except in years of intensive surveys such as in 1989 and 1994). They provide biologists with at least a "snap-shot" of current angling pressure and harvest, and provide a good opportunity for information exchange between anglers and biologists and enforcement personnel".

Spot Creel Surveys

A spot creel survey does not use a sampling theory design to estimate pressure but rather utilizes angler contacts to gather information related to angler success and harvest. Spot creel surveys can be useful when the primary objective is to collect catch rate information or biological information (length, weight, age structures, etc.), and can be used for gathering information pertaining to angler demographics, attitudes, and satisfaction. However, care must be taken to limit the amount of bias, or to acknowledge the biases that may be present in the data. If unbiased estimates of catch statistics are desired, an attempt must be made to sample anglers in proportion to the effort or catch occurring. As an example, assume a particular water produces the highest catch rates for trout during May and early June. Because anglers know this, fishing pressure or effort is higher during this period. If a spot creel survey was conducted from April through September with equal effort in each month, a biased estimate of catch rate could result. This could be somewhat offset if the equal survey effort resulted in more interviews during the months of higher angler pressure and catch. Even if a somewhat biased estimate of catch rate is calculated, it can still be a meaningful statistic. It can be useful trend information, provided the spot creel survey is conducted similarly during subsequent years. As an alternative in the above example, an objective for the fishery can be established which sets a goal of a certain catch rate for trout during the months of May and June. Thus, the creel survey needs only be conducted during those months. Time and effort to conduct the survey are less, and the variability in the calculated catch rate is likely reduced.

As with the programmed creel survey, a spot creel survey can be a roving survey and/or an access point survey. Again, to limit introduction of bias, an effort should be made to interview angler types (bank, boat), locations, and time of day proportionate to the distribution of overall pressure across these variables. Obviously, any precise distribution of effort will probably not be known, but creel survey effort can be scheduled according to general observations and what is known about the fishery.

If questions regarding attitudes or satisfaction are asked during a spot creel survey the occurrence of avidity bias should be acknowledged. If the goal is to prevent avid anglers from having a disproportionate influence on the results of the survey, each angler can be asked if they have been surveyed previously during the year. If they respond affirmatively, the questions pertaining to attitude and satisfaction can be omitted for that particular interview. It may be desirable, however, to weight the opinions of anglers in relative proportion to the amount of time they spend at the water. In that case, the attitude/opinion questions can be asked during every interview, even if that angler had been interviewed previously.

Boysen Reservoir Spot Creel Survey

Boysen Reservoir has had a continuous spot creel program in effect since a 1993 programmed creel. Spot creel checks are conducted April through October with a goal of four interview days per month. Both weekend days and weekdays are selected at random each month. Interviews conducted by enforcement personnel have augmented the spot creel program. The objectives of the program have been to track changes in catch rate for all species, with primary emphasis on WAE and RBT. A secondary objective has been to track changes in size structure and condition of harvested sportfish species in the reservoir. Typically 500 to 1,000 interviews are conducted annually. Results from the survey have been very useful for corroborating trends observed from the annual gill netting program conducted at the reservoir and in evaluating the RBT stocking program.

Off-site Angler Surveys

Off-site angler surveys are those that are conducted away from the fishing site or are self reported. These include: mail, telephone, angler logs, or card surveys. The basic sampling unit is anglers. Off-site surveys are less desirable than on-site surveys if the primary objective is to obtain catch information or other biological information from the catch. Off-site surveys tend to introduce prestige bias, recall bias (anglers remember events of past fishing incorrectly), nonresponse bias (those that fail to respond to a mail survey may have different catch rates than respondents), errors associated with species identification, and errors in fish measurements. However, mail and phone surveys are well suited to sampling angler opinions and attitudes.

These surveys are generally cheaper than on-site surveys and the number of questions can be greater than is practical when interviewing anglers in the field. If a sampling frame (list of anglers, with addresses and/or telephone numbers) is available, mail or telephone surveys should be given consideration as methods to sample attitudes and opinions of anglers. Obtaining a sampling frame may be the biggest challenge in many cases. A list of State Park season pass holders is one possibility, though use of this type of sampling frame would likely introduce some avidity bias to the survey. A mail survey can be used in conjunction with an on-site survey for gathering more extensive or detailed information. Names and addresses of anglers are recorded during the on-site survey to produce the sampling frame for the mail survey.

Angler Diaries

The use of angler diaries or logs is an inexpensive means of collecting information on angler catch. Because only avid anglers usually participate in these programs, catch rates are biased high. The information can be valid, however, for assessing trends in catch rate for the same group of anglers from year to year or for indices of relative contribution of species to the fishery.

Card Surveys

Card surveys are most often used in Wyoming as complementary surveys to on-site creel surveys. For roving surveys, they allow the attainment of completed trip information that may not otherwise be easily obtainable because of diverse access to the water by anglers. Card surveys also allow for more questions to be asked than during a creel interview. However, if return is not high, serious nonresponse biases can be introduced to the survey. Successful anglers are far more likely to return cards than unsuccessful anglers (Pollock et. al. 1994). Card surveys have proven to be most useful when anglers are directly contacted by the creel clerk. Questions can then be limited to length of trip, total number of each species caught and released and satisfaction. The reasons for the card survey are explained to the angler and the angler is asked to complete the postage paid card at the end of the day and place it in the mail or a drop box. The interview is cross referenced to the card number so the biologist can later turn the incompleted-trip interview into a completed-trip interview.

Miracle Mile Programmed Creel Survey with Cards

Angler return cards (cards) were used in conjunction with a programmed creel survey on the Miracle Mile in 2001. Cards were distributed to all anglers who said they were not done fishing for the day (incomplete trips). Cards were postage-paid or anglers could return cards at the Miracle Mile in one of two card boxes. Individual cards were numbered allowing a specific card to reference a specific interview. During the eight-month survey, nearly 3,000 cards were given to anglers who had not finished fishing for that day. Over 25% of the cards were returned, increasing the percentage of completed trips from 10% without card data to 33% (Mavrakis 2002). Estimates of total catch, harvest, catch rate and trip length all increased with card data. Using card data, CVs were between 5% and 10% for the above-mentioned parameters. Since angler numbers are estimated by dividing the estimate of angler hours by trip length, the estimate of angler numbers decreased from nearly 24,000 without the cards to fewer than 15,000 with the cards. Cards were an inexpensive addition to the Miracle Mile creel survey. Total cost for the cards including printing and postage was under $500. Cards allowed data collection from a group of anglers which would typically be under sampled with a traditional creel survey. The isolation of the Miracle Mile translates into most anglers spending at least one night camping or staying at a guest ranch. These anglers typically fish the dusk period of the day and are very difficult for the creel clerk to adequately sample. Future surveys may be able to take advantage of using cards and reducing creel clerk time. The clerk could interview anglers for a short period of time at the Miracle Mile several times a month and hand out cards. This clerk could then spend the majority of his time on another close-by water, essentially getting two creel surveys for the price of one. Additionally, cards may allow us to ask more detailed or water-specific questions that could help guide future management directions.

Mail and Telephone Surveys

Mail and telephone surveys are generally contracted to outside parties. Wyoming has a long history of using surveys to assess not only the attitudes and preferences of outdoor enthusiasts but also their economic valuation and social contributions. Early surveys (Phillips and Ferguson 1977; Phillips and Buchanan1980) combined hunting and fishing and were designed primarily to assess economic expenditures associated with these activities. However, data were collected beginning in 1975 regarding the attitudes of participants that allowed assessment of long-term trends regarding some specific issues. Since then a series of mail surveys has provided WGFD with information on angler desires and trend in these desires (Wolff et al. 1985; Wiley et al. 1988; Anderson et al. 1990; Wenzel and Hubert 1995; Hebdon and Hubert 1999). Statewide angler surveys are conducted and coordinated through the Fish Division Administration approximately every five years.

Intensity of Survey Effort

Regardless of the type of survey chosen, the intensity and frequency of surveys should be determined by the needs and comfort level of managers. The intensity of the survey should reflect the effort needed to provide a meaningful evaluation of the established objectives. Intensity can be measured by number of survey days completed, number of interviews conducted, or number of survey forms or cards returned. It is of little value to conduct a survey at an intensity level that produces estimates that are so questionable that managers are unwilling to utilize them for implementing changes or making decisions regarding fisheries management.

Summary

In summary, assessment of a large standing water fishery often includes the determination of angler success or satisfaction. To make this determination requires that anglers be surveyed by some means. The type of survey method used and the extent to which it is used should only be determined after specific objectives and goals are set in regards to the management of the fishery. In this way the angler surveys can be efficiently designed to provide the information needed to evaluate goals and objectives without adding unneeded time and expense for obtaining information that is secondary or irrelevant. Generally, catch rate is the minimum value that should be estimated during a survey. This allows for a common statistic that can be compared among waters. It is recommended that all major waters should have some type of angler survey conducted at a minimum of every five years.

The tables at the end of this chapter should be used to help determine the most appropriate angler survey design.

	Survey Alternatives								
Which of the following are important?	Program	Short Term Program	Index Counts	Road Block	Spot	Angler Diaries	Creel Cards	Mail	Phone
Estimates of total catch and/or pressure for multiple strata	◎	●	●	○	●	●	◓	●	●
Estimate of catch rate for multiple strata	◎	●	●	○	◎	◒	○	●	●
Trend data related to catch. Frequent estimates of total catch and/or catch rate for a few strata	◒	◎	●	◓	○	◒	○	◒	◒
Trend data related to pressure. Frequent estimates of pressure for a few strata.	◒	◎	◎	◎	◒	●	●	◒	◒
Angler attitudes or opinions regarding specific questions.	○	○	◒	◒	○	●	◓	◎	◎
Biological data if anglers harvest a significant number of fish	◎	◓	●	○	◓	○	◒	●	●
Biological data if anglers release most fish	◒	◒	●	●	●	○	●	●	●
Species composition of the catch – if anglers harvest a significant number of fish	◎	◓	●	◓	◓	○	○	◒	◒
Species composition of the catch – if anglers release most fish	◒	◒	●	●	●	○	◒	◒	◒
Species composition of the water	●	●	●	●	●	●	●	●	●

◎ Very good tool

◓ Good tool

○ Could be used to achieve objective if carefully designed

◒ May provide some help in achieving objective if carefully designed, but not recommended

● Inappropriate tool

Survey Requisites

	You should be able to answer "Yes" to the following questions associated with each tool, if you are going to use that tool?								
	Program	Short Term Program	Index Counts	Road Block	Spot	Angler Diaries	Creel Cards	Mail	Phone
Are you willing to commit a substantial (> 500 hours) amount of time and money to the survey?	**Yes**								
If the water is large with high shoreline development, are funds available for aerial counts?	**Yes**								
Do you have access to contact information (addresses and phone numbers) for a list of anglers that fish the water of interest?								**Yes**	**Yes**
Is access to the water restricted to one or two major roadways or is parking at the water restricted to one or two parking areas?				**Yes**					
Is fishing pressure concentrated during one or two relatively short periods of time?		**Yes**		**Yes**					
Are you willing to base management decisions on trend data that is collected during a relatively short, but frequently repeatable period of time?		**Yes**		**Yes**					

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APPENDIX I

Data Forms

Wyoming Standard Data Sheet - Standing Waters

Water Name_______________________________________ WS-01 01/2003
Gear Type_________________ **Collectors**_________________________________
Comments:
____
____
____

Net Number____ **Depth** _________ - _________
GPS UTM: Zone_____**E**____________**N**_______________

Date Set ________/________/________ **Time Set**___________________
Date Lifted ________/________/________ **Time Lifted**________________
Total Hours Set ____________

	Species	Length	Weight				Species	Length	Weight		
1						36					
2						37					
3						38					
4						39					
5						40					
6						41					
7						42					
8						43					
9						44					
10						45					
11						46					
12						47					
13						48					
14						49					
15						50					
16						51					
17						52					
18						53					
19						54					
20						55					
21						56					
22						57					
23						58					
24						59					
25						60					
26						61					
27						62					
28						63					
29						64					
30						65					
31						66					
32						67					
33						68					
34						69					
35						70					

Volumetric Zooplankton Collection
Data Entry Sheet

Water Name__________________ **Collectors**_____________________
Date__________________________ **Time of Day**___________________

	Volumetric Measurements							
Station	**I**		**II**		**III**		**IV**	
Description of Location								
Sample Number								
153 micron mesh								
500 micron mesh								
750 micron mesh								

Secchi Disk: ____________ **Mean Ratio:** __________

Weather conditions: ____

Temperature and Dissolved Oxygen Profile

Depth		Temp	D.O.

Depth		Temp	D.O.

APPENDIX II

Species Codes

Species Name	Species Code	Scientific Name
Burbot	BBT	Lota lota
Boreal Chorus Frog	BCF	Pseudacris triseriata
Bluehead Sucker	BHS	Catostomus discobolus
Brook Trout	BKT	Salvelinus fontinalis
Black Bullhead	BLB	Ameiurus melas
Black Crappie	BLC	Pomoxis nigromaculatus
Bullfrog	BLF	Rana catesbeiana
Bluegill	BLG	Lepomis macrochirus
Brassy Minnow	BMN	Hybognathus hankinsoni
Bigmouth Shiner	BMS	Notropis dorsalis
Brown Trout	BNT	Salmo trutta
Boreal Toad	BOT	Bufo boreas
Bear River Cutthroat	BRC	Oncorhynchus clarki
Brook x Temiscamie	BXT	Salvelinus fontinalis
Channel Catfish	CCF	Ictalurus punctatus
Creek Chub	CKC	Semotilus atromaculatus
Coho Salmon	COS	Oncorhynchus kisutch
Colorado River Cutthroat	CRC	Oncorhynchus clarki
Carp	CRP	Cyprinus carpio
Common Shiner	CSH	Luxilus cornatus
Common Snapping Turtle	CST	Chelydra serpentina
Cutthroat Trout	CUT	Oncorhynchus clarki
Eagle Lake Rainbow Trout	ELR	Oncorhynchus mykiss
Emerald Shiner	EMS	Notropis atherinoides
Flathead Chub	FHC	Platygobio gracilis
Fathead Minnow	FHM	Pimephales promelas
Firehole Rainbow	FHR	Oncorhynchus mykiss
Florida Largemouth Bass	FLB	Micropterus salmoides
Flathead Catfish	FLC	Pylodictis olivaris
Flannelmouth Sucker	FMS	Catostomus latipinnis
Fall Rainbow	FRB	Oncorhynchus mykiss
Finescale Dace	FSD	Phoxinus neogaeus
Freshwater Drum	FWD	Aplodinotus grunniens
Western Mosquitofish	GAM	Gambusia affinis
GSF X BLG Hybrid	GBH	
Great Basin Spadefoot	GBT	Spea intermontana
Goldbow	GBW	
Grass Carp	GCP	Ctenopharyngodon idella
Goldeye	GDE	Hiodon alosoides
Golden Trout	GDT	Oncorhynchus aguabonita
Goldfish	GOF	Carassius auratus
Golden Shiner	GOS	Notemigonus crysoleucas
Great Plains Toad	GPT	Bufo cognatus
Gerrard Rainbow	GRB	Oncorhynchus mykiss
Grayling	GRL	Thymallus arcticus
Green Sunfish	GSF	Lepomis cyanellus
Guppy	GUP	Poecilia reticulata
Gizzard Shad	GZS	Dorosoma cepedianum
Hornyhead Chub	HHC	Nocomis biguttatus
Iowa Darter	IDT	Etheostoma exile
Johnny Darter	JDT	Etheostoma nigrum
Kemmerer City Rainbow Trout	KCR	Oncorhynchus mykiss
Kokanee Salmon	KOE	Oncorhynchus nerka

Species Name	Species Code	Scientific Name
Kamloops Rainbow	KRB	Oncorhynchus mykiss
Kendall Warm Springs Dace	KWD	Rhinichthys osculus
Lake Trout	LAT	Salvelinus namaycush
Lake Chub	LKC	Couesius plumbeus
Largemouth Bass	LMB	Micropterus salmoides
Longnose Dace	LND	Rhinichthys cataractae
Longnose Sucker	LNS	Catostomus catostomus
Leatherside Chub	LSC	Gila copei
McConaughy Rainbow Trout	MCR	Oncorhynchus mykiss
Mottled Sculpin	MSC	Cottus bairdi
Mountain Sucker	MTS	Catostomus platyrhynchus
Mountain Whitefish	MWF	Prosopium williamsoni
Northern Leopard Frog	NLF	Rana pipiens
Native Non Game	NNG	
No Data/Unknown	NOD	
Northern Pike	NOP	Esox lucius
Pearl Dace	NPD	Margariscus margarita
Shorthead Redhorse	NRH	Moxostoma macrolepidotum
Ornate Box Turtle	OBT	Terrapene ornata
Orange Throat Darter	ODT	Etheostoma spectabile
Ohrid Trout	OHT	Salmo letnica
No fish Present	OOO	
Plains Killifish	PKF	Fundulus zebrinus
Pumpkinseed	PMK	Lepomis gibbosus
Plains Minnow	PMN	Hybognathus placitus
Paiute Sculpin	PSC	Cottus beldingi
Plains Spadefoot	PST	Spea bombifrons
Plains Topminnow	PTM	Fundulus sciadicus
Quillback	QBK	Carpiodes cyprinus
Rainbow Trout	RBT	Oncorhynchus mykiss
River Carpsucker	RCS	Carpiodes carpio
Red Shiner	RDS	Cyprinella lutrensis
Redear Sunfish	RES	Lepomis microlophus
Rock Bass	RKB	Ambloplites rupestris
River Strain Rainbow Trout	RRB	Oncorhynchus mykiss
Redside Shiner	RSS	Richardsonius balteatus
Roundtail Chub	RTC	Gila robusta
River Shiner	RVS	Notropis blennius
RBT X CUT Hybrid	RXC	
Tiger Salamander	SAL	Ambystoma tigrinum
Sauger	SAR	Stizostedion canadense
Sand Shiner	SDS	Notropis stramineus
Sturgeon Chub	SGC	Macrhybopsis gelida
Smallmouth Bass	SMB	Micropterus dolomieu
Suckermouth Minnow	SMM	Phenacobius mirabilis
Western Silvery Minnow	SMN	Hybognathus argyritis
Shovelnose Sturgeon	SNS	Scaphirhynchus platorynchus
Speckled Dace	SPD	Rhinichthys osculus
Spotted Frog	SPF	Rana pretiosa
Splake	SPK	
Spring Rainbow	SRB	Oncorhynchus mykiss
Snake River Cutthroat	SRC	Oncorhynchus clarki
Stonecat	STC	Noturus flavus

Species Name	Species Code	Scientific Name
Brook Stickleback	STK	Culaea inconstans
Central Stoneroller	STR	Campostoma anomalum
Spottail Shiner	STS	Notropis hudsonius
Temiscamie Brook	TBK	Salvelinus fontinalis
Tiger Trout (BKT X BNT)	TGT	
Tiger Muskie	TIM	
Any Trout	TRT	
Utah Chub	UTC	Gila atraria
Utah Sucker	UTS	Catostomus ardens
Walleye	WAE	Stizostedion vitreum
Wood Frog	WDF	Rana sylvatica
White Bass	WHB	Morone chrysops
White Crappie	WHC	Pomoxis annularis
White Sucker	WHS	Catostomus commersoni
Woodhouse's Toad	WHT	Bufo woodhousii
Wiper	WIP	
Western Painted Turtle	WPT	Chrysemys picta
Western Softshell Turtle	WST	Apalone spiniferus
Wyoming Toad	WYT	Bufo baxteri
No preference	XXX	
Yellow Perch	YEP	Perca flavescens
Yellowstone Cutthroat	YSC	Oncorhynchus clarki

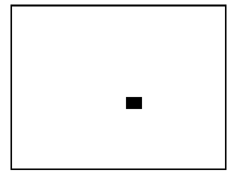
Revised Date
January 2003

APPENDIX III

Lakes and Reservoirs

Regional fisheries managers were asked to provide information about lakes and reservoirs they felt would benefit from standardized sampling under the guidelines offered in this manual. Information requested for each water included management concept, full pool capacity, elevation, species managed for, species present, and management goals and objectives. Thirty three lakes and reservoirs were listed.

Alcova Reservoir
CR450390NA
1UR



Management Concept
Basic Yield

Surface Area at Full Pool
2,260 acres

Elevation
5,444 feet

Species Managed For
RBT, WAE

Species Present
BMS, BNT, CRP, CUT, EMS, FHM, GSF, IDT, JDT, LKC, LNS, RBT, SDS, STS, WAE, WHS

Management Goals & Objectives Statement
Goals:

To manage Alcova Reservoir to consistently provide satisfactory sport fishing opportunity for RBT though annual stocking.

Objectives:

1. Maintain July-August angler catch rates of RBT at 0.50 fish/hour.
2. Maintain CPUE of WAE in spring experimental gill nets below 0.40 fish/hour.

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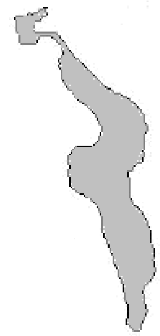
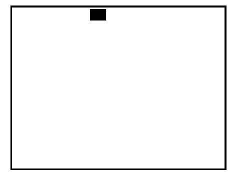
January 2003

Big Horn Reservoir
CY823040BN
2BL





Management Concept
Basic Yield

Surface Area at Full Pool
6,834 acres

Elevation
3,640 feet

Species Managed For
CCF, SAR, NNG

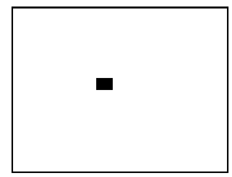
Species Present
BBT, BLB, CCF, CRP, FHC, LNS, SRH, PMN, RCS, SAR, BLC, STC, EMS, WAE, WHS, SNS

Management Goals & Objectives Statement

Focus management on native species, primarily channel catfish, burbot, and sauger.
Enhance habitat for native species via water level manipulation and a minimum pool agreement.
Determine limiting factors for channel catfish and burbot and work to enhance abundance of these species.
Use annual monitoring to assess relative abundance of species over time and determine the need for future regulation changes.
Continue to work with cooperating agencies, Montana Department of Fish Wildlife and Parks, National Park Service, and U.S. Bureau of Reclamation, to enhance the fishery and protect native species.

Revised Date
January 2003

Boysen Reservoir
LR420114FT
6BO



Management Concept
Basic Yield

Surface Area at Full Pool
19,560 acres

Elevation
4,725 feet

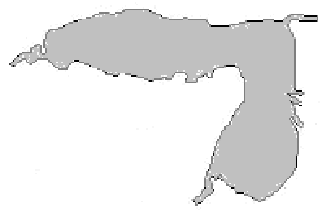
Species Managed For
WAE, RBT, CCF, BBT,
SAR

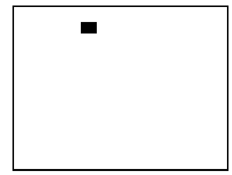
Species Present
BBT, BLB, BLC, BNT, CCF, CKC, CRP, EMS, FHM, JDT, LKC, LMB, LND,
LNS, NRH(SRH), PKF, RBT, RCS, SAR, SDS, STS, WAE, WHS, YEP

Management Goals & Objectives Statement
Maintain angler catch rates above 0.40 fish/hr from May-August.
Manage RBT as a trophy fishery.

Revised Date
January 2003

Buffalo Bill Reservoir
CY420152PK
2BB





Management Concept
Wild

Surface Area at Full Pool
8,315 acres

Elevation
5393.5 feet

Species Managed For
RBT, YSC, LAT

Species Present
BKT, BNT, CRP, FHM, LAT, LKC, LND, LNS, MTS, MWF, RBT, RXC, SRC, WHS, YEP, YSC

Management Goals & Objectives Statement

Goals:

1. Manage reservoir as a wild fishery.
2. Manage reservoir as integral part of Upper Shoshone River Drainage.

Objectives:

1. Maintain a harvest of 1.2 wild trout per trip at a rate of 0.35 fish per hour, comprised of rainbow (average 14.5 in and 1.0 lb); brown trout (average 14.5 in and 1.0 lb); Yellowstone cutthroat (average 14.5 in and 1.0 lb); lake trout (average 16.5 in and 1.1 lb).
2. Continue and/or adjust Upper Shoshone River Drainage regulations as needed to maintain a wild trout fishery as described above.
3. Continue to improve habitat and use best management practices to protect and enhance native Yellowstone cutthroat populations wherever possible.
4. Sample annually to determine population and growth trends. Adjust management practices as needed to maintain goals and objectives.

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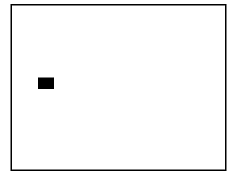
Burnt Lake
PE140497SE
7BU



Management Concept
Basic Yield

Surface Area at Full Pool
815 acres

Elevation
7,916 feet

Species Managed For
LAT, RBT

Species Present
BKT, FMS, LAT, MTS, RBT, RTC, BRS, CUT, WHS

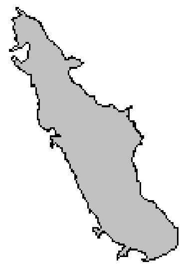
Management Goals & Objectives Statement

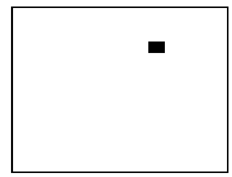
Achieve a LAT fishery with an angler catch rate of 0.15 fish/hr and a gill net CPUE of 0.20 fish/hr.
Maintain a sufficient spawning population of RBT to maintain a RBT fishery in Burnt Lake (0.10 RBT/angler-hr, 0.20 RBT/ GN-hr) and Fall Creek (0.40 fish/angler-hr).

Revised Date
January 2003

Lake DeSmet
SN430227JN
8DS

Management Concept
Basic Yield





Surface Area at Full Pool
3,200 acres

Elevation
4610 feet

Species Managed For
ELR

Species Present
BLC, BNT, CKC, CRP, ELR, ELS, FHM, RKB, WHS, YEP, WAE

Management Goals & Objectives
Goals:

Provide anglers with a quality trout fishing opportunity.

Objectives:

1) Maintain angler catch rate of 0.5 fish/hr.
2) Maintain a RBT PSD of 40.

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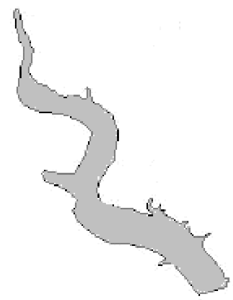
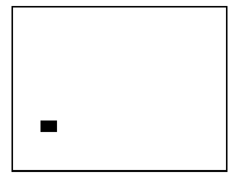
Fontenelle Reservoir
GR440005LN
3FC





Management Concept
Basic Yield

Surface Area at Full Pool
8,819 acres

Elevation
6,505 feet

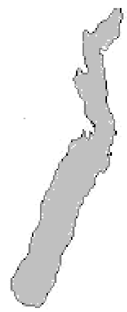
Species Managed For
BNT, RBT, KOE

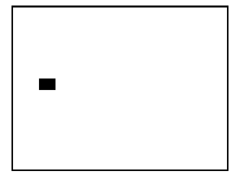
Species Present
BNT, CRP, FHM, FMS, KOE, MTS, MWF, RBT, SMB, SPD, SRC, UTC

Management Goals & Objectives Statement
Maintain/enhance catch rates on trout in Fontenelle Reservoir at historic levels of at least 0.20 fish/hour.
Plant RBT to maintain basic yield sport fishery.
BNT population will be maintained through natural recruitment.
Stock 150,000 KOE when available.

Revised Date
January 2003

Fremont Lake
PE140654SE
7FR





Management Concept
Trophy

Surface Area at Full Pool
4,996 acres

Elevation
7,418 feet

Species Managed For
LAT, RBT, KOE

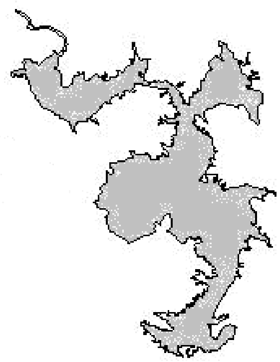
Species Present
BNT, CUT, KOE, LAT, MTS, RBT, RTC, WHS, BKT, BRS, FMS, MSC, SPD

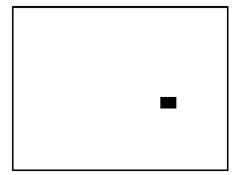
Management Goals & Objectives Statement

Maintain a lake trout fishery with a gill-net CPUE of 0.05 fish/hr fish greater than 18 in, median length of 16.0 in, and an angler catch rate of 0.10 fish/hr.
Achieve a secondary fishery for rainbow trout with a catch rate of 0.10 fish/hr for boat anglers and 0.15 fish/hr for bank anglers.
Develop a kokanee population that prevents a decrease in lake trout condition and is actively pursued by 10% of the boat anglers.

Revised Date
January 2003

Glendo Reservoir
CR450145PE
1GO





Management Concept
Basic Yield

Surface Area at Full Pool
12,365 acres

Elevation
4,653 feet

Species Managed For
CCF, WAE, YEP

Species Present
BLC, BNT, CCF, CRP, EMS, FHM, GSF, IDT, JDT, LMB, LNS, NRH, QBK, RBT, RDS, SDS, STS, WAE, WHC, WHS, YEP

Management Goals & Objectives Statement
Goals:

To manage Glendo Reservoir to provide a satisfactory sport fishing opportunity for WAE, CCF, and YEP.

Objectives:

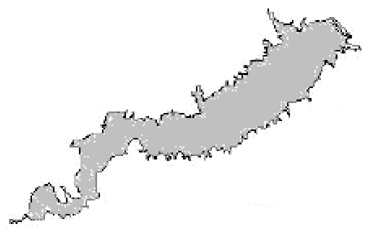
1. Maintain April-July WAE catch rates of at least 0.3/hour.
2. Maintain populations of YEP and CCF. Monitor populations through gill netting.
3. Maintain a WAE PSD EG of at least 45.
4. Ensure adequate forage to maintain WAE Wr of 85 (for all RSD size categories) by occasional GZS stocking.

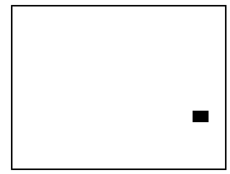
Revised Date
January 2003

Grayrocks Reservoir
LE450005PE
5WW

Management Concept
Basic Yield

Surface Area at Full Pool
4,333 acres





Elevation
4,250 feet

Species Managed For
WAE, CCF, TIM

Species Present
BLB, BLC, BMN, BNT, CCF, CKC, CRP, FHM, FWD, GSF, GZS, IDT, LMB, LND, SRH, PKF, PMK, QBK, RDS, SMB, STC, STS, TIM, WAE, WHS, YEP

Management Goals & Objectives Statement

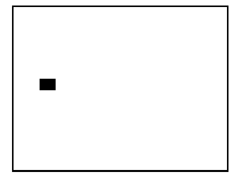
All the Laramie Plains Lakes are managed to maintain or expand fishing opportunity and access, along with providing diverse fishing opportunities.

Maintain a walleye harvest of two fish per trip at a rate of 0.4 fish per hour for the year. During June, maintain a walleye catch rate of 1.0 fish/hr.
Maintain the average size of walleye harvested at 16.0 inches with an average weight of 1.7 pounds.
Implement regulations to maintain 1 and 2 above.
Continue with efforts to diversify the forage base.
Continue with efforts to expand black crappie populations to improve shore angling.
Maintain a consistent walleye fingerling stocking program (100 fingerlings/acre) for at least four years, because of the change from fry to fingerlings initiated in 1995; because it takes four years for walleye to be fully recruited (Marwitz 1994), and because another creel survey is recommended in 1999
Use incremental relative stock density (RSD) data (Willis et al. 1993) to guide future management decisions (such as fishing regulation changes) on Grayrocks Reservoir. I suggest that the RSD S-Q should be set at an objective of 56%, RSD Q-P should be set at an objective of 42%, and RSD P-M should be set at an objective of 5%.

Revised Date
January 2003

Halfmoon Lake
PE140657SE
7HA

Management Concept
Basic Yield



Surface Area at Full Pool
921 acres

Elevation
7,599 feet

Species Managed For
LAT, RBT

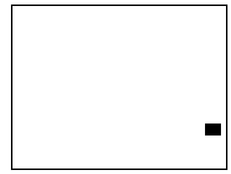
Species Present
BKT, BNT, FMS, LAT, LND, MSC, MTS, RBT, RTC, SPD, WHS

Management Goals & Objectives Statement

Maintain a basic yield lake trout fishery with an angler catch rate of 0.20 fish/hr where 30% of the fish are greater than 18 in.
Achieve a secondary fishery for rainbow trout with an angler catch rate of 0.20 fish/hr.

Revised Date
January 2003

Hawk Springs Reservoir
LE450230GN
5WW



Management Concept

Basic Yield

Surface Area at Full Pool

1,280 acres

Elevation

4,475 feet

Species Managed For

WAE, LMB, WHC,
CCF

Species Present

BLG, BNT, CCF, CRP, GSF, GZS. JDT, LMB, LNS, SRH, RDS, SMB, STC, STS, WAE, WHC, WHS, YEP

Management Goals & Objectives Statement

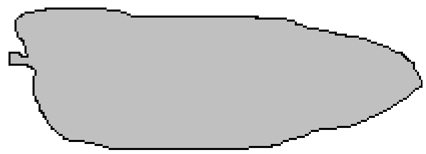
All the Laramie Plains Lakes are managed to maintain or expand fishing opportunity and access, along with providing diverse fishing opportunities.

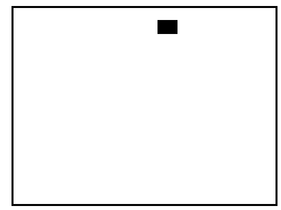
Maintain a walleye harvest of two fish per trip at a rate of 0.4 fish per hour for the year
Maintain the average size of walleye harvested at 16.0 inches with an average weight of 1.6 pounds.
Implement regulations to maintain 1 and 2 above.
Continue with efforts to diversify the forage base. Maintain a good forage base by annually stocking adult GZS in the spring.
Continue with efforts to expand black crappie populations to improve shore angling.
Maintain a consistent walleye fingerling stocking program (100 fingerlings/acre) for at least four years, because of the change from fry to fingerlings initiated in 1995; because it takes four years for walleye to be fully recruited (Marwitz 1994), and because another creel survey is recommended in 1999. If fingerling walleye are not available then stock one million walleye fry to maintain catch rates.

Revised Date
January 2003

Healy Reservoir
SN431134JN
8CC

Management Concept
Trophy





Surface Area at Full Pool
250 acres

Elevation
4290 feet

Species Managed For
RBT, SRC

Species Present
BKT, BNT, FHM, LNS, NRH, RBT, SRC, STC, WHS, YEP

Management Goals & Objectives
Goals:

Provide anglers with a quality angling experience and the opportunity to catch a large trout.

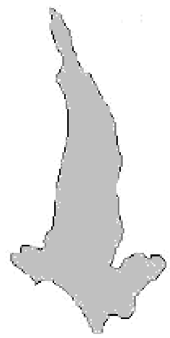
Objectives:

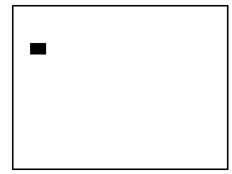
1) Maintain an angler trout catch rate of at least 0.5 fish/hr.
2) Maintain a RBT PSD of 25.

Revised Date
January 2003

Jackson Lake
JN410320TN
4AJ

Management Concept
Basic Yield





Surface Area at Full Pool
25,730 acres

Elevation
6,769 feet

Species Managed For
LAT, SRC

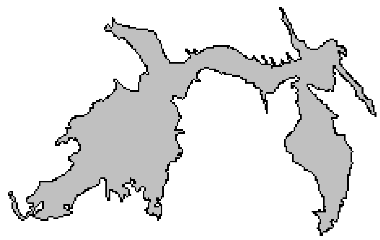
Species Present
BNT, LAT, MSC, MWF, RSS, SPD, SRC, UTC, UTS

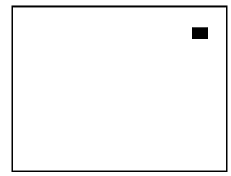
Management Goals & Objectives Statement
The principle management objective for Jackson Lake is to maintain a basic yield fishery while also allowing for trophy lake trout. Jackson Lake provides a fishing opportunity for anglers comprised largely of tourists. Current management objectives are to maintain the mean length of lake trout at 17.0 inches with an average harvest rate of 0.5 lake trout per hour.

Approximately 36,000 fin-clipped catchable lake trout are stocked in Jackson Lake annually. Starting in 1998, all 36,000 lake trout were reared at the Jackson National Fish Hatchery. Stocking is used to improve catch rates and relieve fishing pressure on wild fish. Typically, the creel consists of from 10 to 20% hatchery reared lake trout.

Revised Date
January 2003

Keyhole Reservoir
SN460371CK
8KH





Management Concept
Basic Yield

Surface Area at Full Pool
9,420 acres

Elevation
4099 feet

Species Managed For
CCF, NOP, SMB, WAE

Species Present
BLB, BLC, CCF, CRP, EMS, FHC, FHM, FWD, GSF, GZS, LMB, NOP, NRH, PMN, RCS, RDS, SDS, STS, WAE, WHC, WHS, YEP

Management Goals & Objectives:
Goals
To manage Keyhole Reservoir to consistently provide satisfactory sport fishing opportunity through annual WAE and NOP stocking.

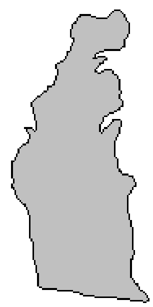
Objectives:

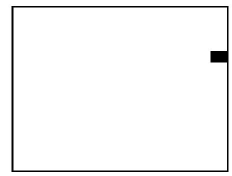
1) Maintain a WAE angler catch rate of 0.25 fish/hr.
2) Maintain a WAE PSD of 25.
3) Maintain a NOP RSD-30 of 10.

Revised Date
January 2003

LAK Reservoir
SN460007WN
8CR

Management Concept
Basic Yield





Surface Area at Full Pool
120 acres

Elevation
4374 feet

Species Managed For
WAE

Species Present
BNT, GOS, GSF, LMB, SMB, TIM, RBT, WAE, WHS

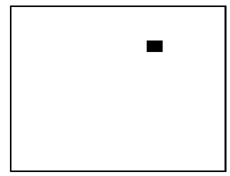
Management Goals & Objectives:
Goals
Provide anglers with a quality angling experience and the opportunity to catch a unique species.

Objectives:

1) Maintain WAE net CPUE of 0.3 fish/hr.
2) Maintain a GSF trap net CPUE <=5.0.

Revised Date
January 2003

Lake DeSmet
SN430227JN
8DS



Management Concept
Basic Yield

Surface Area at Full Pool
3,200 acres

Elevation
4610 feet

Species Managed For
ELR

Species Present
BLC, BNT, CKC, CRP, ELR, ELS, FHM, RKB, WHS, YEP, WAE

Management Goals & Objectives
Goals:

Provide anglers with a quality trout fishing opportunity.

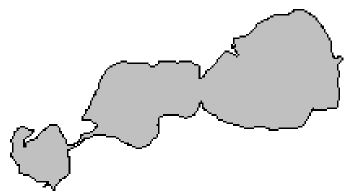
Objectives:

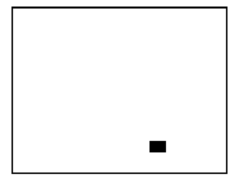
1) Maintain angler catch rate of 0.5 fish/hr.
2) Maintain a RBT PSD of 40.

Revised Date
January 2003

Lake Hattie
LE450541AY
5PL

Management Concept
Basic Yield





Surface Area at Full Pool
2,000 acres

Elevation
7,255 feet

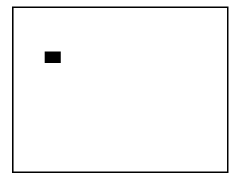
Species Managed For
RBT, BNT, LAT

Species Present
BNT, ELR, KOE, LNS, RBT, SPK, SRC, WHS, YEP

Management Goals & Objectives Statement
All the Laramie Plains Lakes are managed to maintain or expand fishing opportunity and access, along with providing diverse fishing opportunities. Maintain a trout catch rate of > 0.5 fish/hr at an average size of > 14.0 inches.

Revised Date
January 2003

Lower Slide Lake
JN310235TN
4GV



Management Concept
Basic Yield

Surface Area at Full Pool
1,134 acres

Elevation
6, 908 feet

Species Managed For
SRC

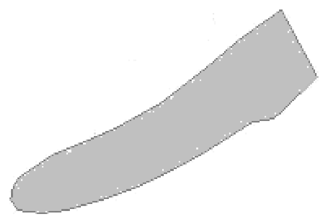
Species Present
LAT, MWF, SRC, UTC, UTS, BHS

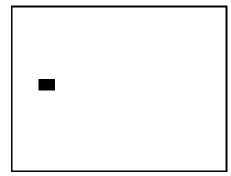
Management Goals & Objectives Statement
Management objectives for Lower Slide Lake are to maintain a catch rate of 0.5 fish per hour. Currently, 5,000 SRC are stocked annually. The lake is stocked to increase catch rates and provide a readily available lake fishery close to the town of Jackson. In low precipitation years, the stocked fish are able to take advantage of elevated plankton levels.

Revised Date
January 2003

Middle Piney Lake
PE140945SE
7MP

Management Concept
Basic Yield





Surface Area at Full Pool
142 acres

Elevation
8,841 feet

Species Managed For
LAT, RBT

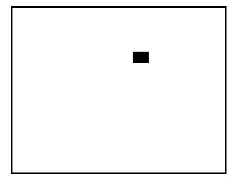
Species Present
BKT, BNT, CUT, KOE, LAT, RBT

Management Goals & Objectives Statement

Maintain present angler success at Middle Piney Lake. Trend data suggest maintaining an average gill net CPUE of 0.6 lake trout/hour and 1.5 rainbow trout/hour.
The average length for lake trout should be 16.0 in (range 14 - 24 in) and the average length for rainbow trout should be 10.0 in (range 8 - 14 in).
Limited creel census information indicates an average angler catch rate of one trout/hour should be maintained.

Revised Date
January 2003

Muddy Guard Reservoir #1
SN431193JN
8CW



Management Concept
Trophy

Surface Area at Full Pool
27 acres

Elevation
5240 feet

Species Managed For
RBT

Species Present
RBT, BNT, EMS, FHM, LND, WHS, MTS, SPK

Management Goals and Objectives:
Goals:

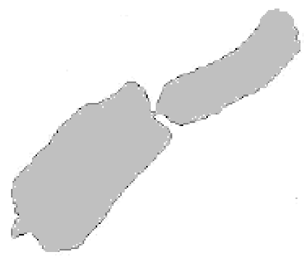
Provide an opportunity to catch a trout greater than 20 inches.

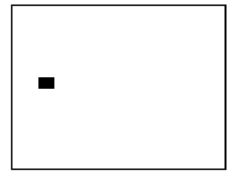
Objectives:

1) Maintain a net CPUE of 1.0 trout/hr.
2) Maintain a RBT PSD of 40.

Revised Date
January 2003

New Fork Lakes
PE240893SE & PE240894SE
7NF





Management Concept
Basic Yield

Surface Area at Full Pool
1,237 acres

Elevation
7,819 feet

Species Managed For
RBT, LAT, KOE

Species Present
BKT, FMS, LAT, MTS, MWF, RBT, KOE, BRS

Management Goals & Objectives Statement

Maintain a LAT fishery with a boat angler catch rate of 0.10 fish/hr.
Maintain a KOE spawning run for egg-taking of 4,000 males that average 11 in length.
Maintain a family fishery for RBT with a bank angler catch rate of 0.50 fish/hr.

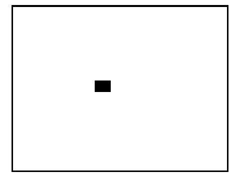
Revised Date
January 2003

Ocean Lake
LR420028FT
6OC

Management Concept
Basic Yield

Surface Area at Full Pool
6,100 acres

Elevation
5,234 feet



Species Managed For
WAE, BBT, BLC, WHC

Species Present

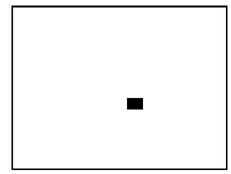
BBT, BLC, BLG, CRP, EMS, FHM, JDT, LKC, LMB, LND, LNS, PKF, SDS, STS, WHC, WHS, WAE, YEP

Management Goals & Objectives Statement

Manage the lake to provide a consistently satisfactory walleye fishery through annual stocking.
Maintain CPUE of WAE from fall experimental gill nets above 0.25/hour.

Revised Date
January 2003

Pathfinder Reservoir
CR450435NA
1UR



Management Concept
Basic Yield

Surface Area at Full Pool
20,000 acres

Elevation
5,858 feet

Species Managed For
RBT, WAE

Species Present
BMS, BNT, CKC, CRP, EMS, FHM, GZS, IDT, JDT, LKC, LNS, RBT, SDS, SRC, STS, WAE, WHS

Management Goals & Objectives Statement
Goal:

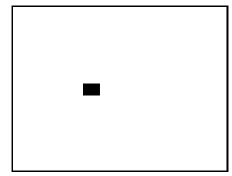
To manage Pathfinder Reservoir to consistently provide satisfactory sprot fishing opportunity for RBT and WAE through annual RBT stocking and manipulation of the wild WAE population.

Objectives:

1. Maintain a May - September stocked RBT angler catch rate of 0.3/hour.
2. Preserve the opportunity for anglers to catch large trout (>20 inches).
3. Maintain RBT FG PSD at least 40.
4. Maintain WAE EG PSD at least 20.

Revised Date
January 2003

Pilot Butte Reservoir
LR420032FT
6WD



Management Concept
Basic Yield

Surface Area at Full Pool
921 acres

Elevation
5,556 feet

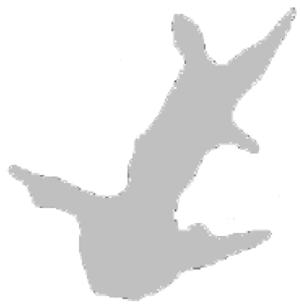
Species Managed For
RBT

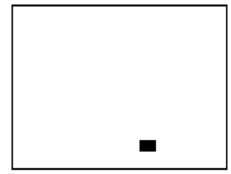
Species Present
BBT, BNT, FHC, LKC, LND, LNS, MWF, WHS, RBT, YEP

Management Goals & Objectives Statement
Manage the reservoir as a basic yield RBT fishery.
Conduct evaluations to determine the feasibility of managing the fishery by stocking smaller RBT. (Currently planned for 2003-2005).

Revised Date
January 2003

Rob Roy Reservoir
LE250718AY
5DC





Management Concept
Basic Yield

Surface Area at Full Pool
800 acres

Elevation
9,470 feet

Species Managed For
RBT, BKT, SPK

Species Present
BKT, BNT, LNS, RBT, SPK, SRC, WHS

Management Goals & Objectives Statement
Goals:

Manage the reservoir under the "Basic Yield" fishery concept

Objectives:

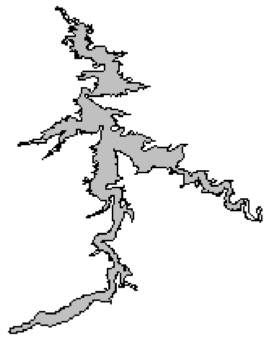
1. Meet the standards for size and success rates per fishermen day that are outlined in the Strategic Plan for waters managed under the "Basic Yield" concept. For rainbow trout these standards are 9.0 inches with a success rate of 1.4 trout per fishermen day.

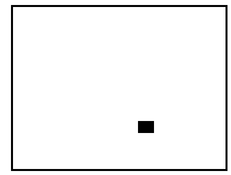
2. Maintain the Strategic Plan standards for rainbow trout with continued annual stocking of approximately 50,000 rainbow trout advanced fingerlings.

Revised Date
January 2003

Seminoe Reservoir
CR450405CN
1UR

Management Concept
Basic Yield





Surface Area at Full Pool
22,000 acres

Elevation
6,361

Species Managed For
BNT, RBT, WAE

Species Present
BMS, BNT, CRP, EMS, FHM, IDT, JDT, LAT, LKC, LNS, RBT, SDS, SRC, WAE, WHS

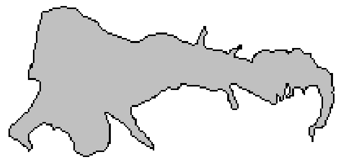
Management Goals & Objectives Statement

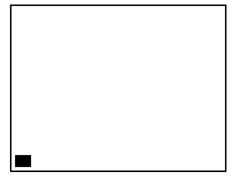
Objectives:

1. Maintain May-August angler catch rates of RBT at 0.40 fish/hour.
2. Maintain May-August angler catch rates of WAE at 0.40 fish/hour.
3. Maintain a RBT PSD of 25 or greater.
4. Maintain a WAE PSD of 45 or greater by 2006.

Revised Date
January 2003

Sulphur Creek Reservoir
GR490325UA
3SR





Management Concept
Basic Yield

Surface Area at Full Pool
560 acres

Elevation
7,200 feet

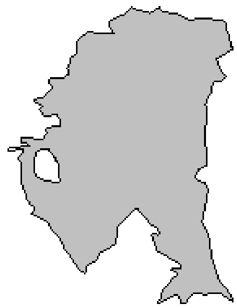
Species Managed For
RBT, BRC, BNT

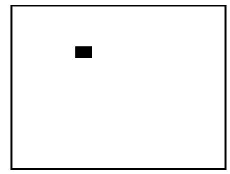
Species Present
BHS, BNT, BRC, CUT, LND, LSC, MTS, RBT, UTS

Management Goals & Objectives Statement
Continue stocking with BNT, RBT, and BRC to provide a diverse basic yield fishery in the Southwest region of Wyoming.
Maintain an average catch per unit effort 0.50 trout per hour.

Revised Date
January 2003

Upper Sunshine Reservoir
CY420055PK
2SR





Management Concept
Basic Yield

Surface Area at Full Pool
600 acres

Elevation
6,587 feet

Species Managed For
YSC

Species Present
Reservoir was dry in September 2002. When water conditions are favorable, reservoir will be restocked with YSC.

Management Goals & Objectives Statement
Goals:

Manage reservoir as a basic yield fishery through stocking of Yellowstone cutthroat.

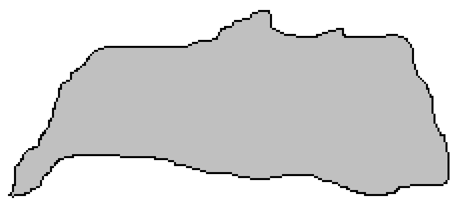
Objectives:

1. Maintain fish population at levels that will provide anglers the opportunity to harvest fish at a success rate to exceed 2.5 fish per day per angler.
2. Maintain growth rates to provide anglers the opportunity to catch trophy size cutthroat (15+ in).
3. Sample reservoir every other year to monitor population and growth. Adjust stocking density as needed to maintain goals and objectives.

Revised Date
January 2003

Viva Naughton Reservoir
GR440255LN
3VR

Management Concept
Basic Yield



Surface Area at Full Pool
1,458 acres

Elevation
7,239 feet

Species Managed For
RBT, BNT

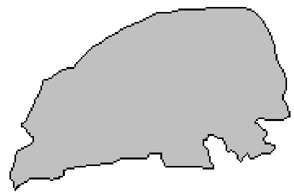
Species Present
RBT, BNT, SPK, MSC, MTS, MWF, SPD, UTC, BRS

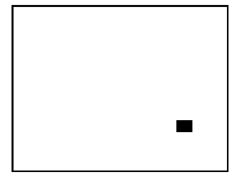
Management Goals & Objectives Statement
Provide a basic yield fishery at Viva Naughton Reservoir through RBT and BNT stocking efforts.
Complete drainage survey to document status and distribution of trout populations and habitat conditions.

Revised Date
January 2003

Wheatland #1 Reservoir
LE450195PE
5WW

Management Concept
Basic Yield





Surface Area at Full Pool
424 acres

Elevation
4,920 feet

Species Managed For
WAE

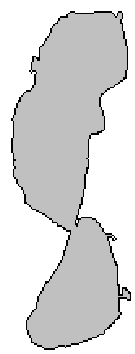
Species Present
BLB, BNT, CPR, JDT, LNS, RBT, STS, WAE, WHS

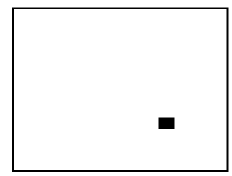
Management Goals & Objectives Statement
All the Laramie Plains Lakes are managed to maintain or expand fishing opportunity and access, along with providing diverse fishing opportunities.
To provide an opportunity for recreationists of Platte County to have access to a lake with clear water to boat, swim, camp and fish.
To provide a warm water fishery during the summer using a basic yield concept.
Return > 1.0 lb of fish to the creel for each 1.0 lb of fish stocked.

Revised Date
January 2003

Wheatland #3 Reservoir
LE450411AY
5PL

Management Concept
Basic Yield





Surface Area at Full Pool
7,597 acres

Elevation
6,940 feet

Species Managed For
RBT

Species Present
BNT, CUT, IDT, JDT, LNS, RBT, SRC, STS, WAE, WHS, YSC

Management Goals & Objectives Statement

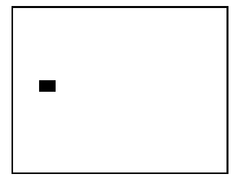
All the Laramie Plains Lakes are managed to maintain or expand fishing opportunity and access, along with providing diverse fishing opportunities.

Maintain a trout catch rate of > 0.5 fish/hr at an average size of > 15.0 inches. Following McDowell's (1984) recommendation of basing stocking levels on 2,150 surface acres of inactive storage capacity, maintain stocking rates at 100 - 150 fish/acre.

Revised Date
January 2003

Willow Lake
PE240851SE
7WI

Management Concept
Basic Yield



Surface Area at Full Pool
1,805 acres

Elevation
7,698 feet

Species Managed For
KOE, LAT

Species Present
BKT, CUT, FMS, KOE, LAT, MTS, RBT, SPD, BRS, MSC, RTC, WHS

Management Goals & Objectives Statement

Maintain a basic yield lake trout fishery with a boat angler catch rate of 0.30 fish/hr.
Maintain a KOE population for diversity and LAT forage.

Revised Date
January 2003